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Lewis Research Center  
Cleveland, Ohio 44135  
May 1978





## PREFACE

This compilation of abstracts describes and indexes the technical reporting that resulted from the scientific and engineering work performed and managed by the Lewis Research Center. All the publications were announced in the 1977 issues of STAR (Scientific and Technical Aerospace Reports) and/or IAA (International Aerospace Abstracts). Included are research reports, journal articles, conference presentations, patents and patent applications, and theses. The importance that Lewis management places on reporting and announcing the results of our technical activities is demonstrated by this document. In 1977 our output was 256 research reports, 233 journal articles and conference presentations, and 224 contractor reports. The arrangement of the material is by NASA subject category as noted in the Contents. The Lewis authored items are listed first in each category followed by the contractor items. Within each of these groups is listed report literature, identified by N-numbers, followed by the journal and conference presentations, identified by A-numbers. A grouping of indexes helps locate specific publications by subject, author (including contractor authors), contractor organization, contract number, and report number.

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# 01 AERONAUTICS (GENERAL)

**N77-18014\*#** National Aeronautics and Space Administration.  
Lewis Research Center, Cleveland, Ohio.

## COMPONENT TEST PROGRAM FOR VARIABLE-CYCLE ENGINES

**c07**  
Albert G. Powers, John B. Whitlow, and Leonard E. Stitt *In its Proc. of the SCAR Conf., Part 1* 1976 p 371-385 refs (For primary document see N77-17996 09-01)  
Avail: NTIS HC A21/MF A01 CSCL 21E

Variable cycle engine (VCE) concepts for a supersonic cruise aircraft were studied. These VCE concepts incorporate unique critical components and flow path arrangements that provide good performance at both supersonic and subsonic cruise and appear to be economically and environmentally viable. Certain technologies were identified as critical to the successful development of these engine concepts and require considerable development and testing. The feasibility and readiness of the most critical VCE technologies was assessed, a VCE component test program was initiated. The variable stream control engine (VSCE) component test program, tested and evaluated an efficient low emission duct burner and a quiet coannular ejector nozzle at the rear of a rematched F100 engine. **Author**

**N77-18015\*#** National Aeronautics and Space Administration.  
Lewis Research Center, Cleveland, Ohio.

## SUPERSONIC CRUISE INLETS FOR VARIABLE-CYCLE ENGINES

**c07**  
David N. Bowditch *In its Proc. of the SCAR Conf., Part 1* 1976 p 387-397 refs (For primary document see N77-17996 09-01)  
Avail: NTIS HC A21/MF A01 CSCL 21E

The performance of candidate supersonic cruise inlets is reviewed and the aerodynamic installation penalties for each type are defined. The main characteristics that affect the airflow schedules of variable cycle engines are defined. These schedules are compared with the airflow schedules of the candidate inlets, and appropriate inlets are matched to the variable-cycle engine characteristics. Auxiliary inlets are also considered. **Author**

**N77-18016\*#** National Aeronautics and Space Administration.  
Lewis Research Center, Cleveland, Ohio.

## CONTROL OF PROPULSION SYSTEMS FOR SUPERSONIC CRUISE AIRCRAFT

**c07**  
Kirby W. Miller and Daniel I. Drain *In its Proc. of the SCAR Conf., Part 1* 1976 p 399-415 refs (For primary document see N77-17996 09-01)  
Avail: NTIS HC A21/MF A01 CSCL 21E

The propulsion control requirements of supersonic aircraft are presented. Integration of inlet, engine, and airframe controls is discussed. The application of recent control theory developments to propulsion control design is described. Control component designs for achieving reliable, responsive propulsion control are also discussed. **Author**

**N77-18018\*#** National Aeronautics and Space Administration.  
Lewis Research Center, Cleveland, Ohio.

## COMPOSITE MATERIALS RESEARCH IN SUPPORT OF SUPERSONIC PROPULSION SYSTEMS

**c07**  
Robert A. Signorelli *In its Proc. of the SCAR Conf., Part 1* 1976 p 457-468 refs (For primary document see N77-17996 09-01)  
Avail: NTIS HC A20/MF A01 CSCL 21E

Two engine components, fan blades and exhaust systems, were selected for composite materials development efforts in support of the supersonic cruise aircraft research (SCAR) engine program. The materials selected were boron/aluminum for fan blades and silicon carbide/superalloy sheet for the exhaust system. The current status of the research into applying these two composite materials to SCAR engines is reviewed. **Author**

**N77-18020\*#** National Aeronautics and Space Administration.  
Lewis Research Center, Cleveland, Ohio.

## AEROACOUSTIC STUDIES OF COANNULAR NOZZLES SUITABLE FOR SUPERSONIC CRUISE AIRCRAFT APPLICATIONS

**c05**  
Orlando A. Gutierrez *In its Proc. of the SCAR Conf., Pt. 2*, 1976 20 p refs (For primary document see N77-18019 09-01)  
Avail: NTIS HC A23/MF A01 CSCL 01C

Research programs were conducted to investigate experimentally the aeroacoustic characteristics of scale model, inverted-velocity profile coannular nozzles. These programs include studies of unsuppressed configurations with and without center plugs over a variety of radius ratios and area ratios. Also included are suppressed configurations, the effect of injectors, and some simulated flight effects. Unsuppressed inverted-velocity profile coannular nozzles seem to allow jet mixing noise compliance with present FAR-36 regulations when applied to supersonic cruise aircraft engine cycles. Simulated flight tests suggest that the aeroacoustic benefits of the inverted-velocity profile coannular nozzles would be maintained in flight. **Author**

**N77-18024\*#** National Aeronautics and Space Administration.  
Lewis Research Center, Cleveland, Ohio.

## TECHNOLOGY FOR CONTROLLING EMISSIONS OF OXIDES OF NITROGEN FROM SUPERSONIC CRUISE AIRCRAFT

**c07**  
Gregory M. Reck and Richard A. Rudey *In its Proc. of the SCAR Conf., Pt. 2*, 1976 22 p refs (For primary document see N77-18019 09-01)  
Avail: NTIS HC A23/MF A01 CSCL 21E

Various experiments are sponsored and conducted by NASA to explore the potential of advanced combustion techniques for controlling aircraft engine emissions into the upper atmosphere. Of particular concern are the oxide of nitrogen (NOx) emissions into the stratosphere. The experiments utilize a wide variety of approaches varying from advanced combustor concepts to fundamental flame tube experiments. Results are presented which indicate that substantial reductions in cruise NOx emissions should be achievable in future aircraft engines. A major NASA program is described which focuses the many fundamental experiments into a planned evolution and demonstration of the prevaporized-premixed combustion technique in a full-scale engine. **Author**

**N77-18992\*#** National Aeronautics and Space Administration.  
Lewis Research Center, Cleveland, Ohio.

## REVISED FORTRAN PROGRAM FOR CALCULATING VELOCITIES AND STREAMLINES ON THE HUB-SHROUD MIDCHANNEL STREAM SURFACE OF AN AXIAL-, RADIAL-, OR MIXED-FLOW TURBOMACHINE OR ANNULAR DUCT. 1: USER'S MANUAL

Theodore Katsanis and William D. McNally Washington Mar. 1977 107 p refs Supersedes NASA-TN-D-7343; N73-26996

(NASA-TN-D-8430; E-8734) Avail: NTIS HC A06/MF A01 CSCL 01A

A FORTRAN 4 computer program was developed that obtains a detailed subsonic or shock-free transonic flow solution on the hub-shroud midchannel stream surface of a turbomachine. The blade row may be fixed or rotating, and the blades may be twisted and leaned. Flow may be axial, mixed, or radial. Upstream and downstream flow variables may vary from hub to shroud, and provision is made to correct for loss of stagnation pressure. The results include velocities, streamlines, and flow angles on the stream surface as well as approximate blade surface velocities. Subsonic solutions are obtained by a finite-difference, stream-function solution. Transonic solutions are obtained by a velocity-gradient method that uses information from a finite-difference, stream-function solution at a reduced mass flow. **Author**

**N77-16986\*** Pratt and Whitney Aircraft, East Hartford, Conn.  
**AERODYNAMIC AND ACOUSTIC TESTS OF DUCT-BURNING TURBOFAN EXHAUST NOZZLES** Final Report  
 Hilary Kozlowski and Allan B. Packman Washington NASA  
 Dec. 1976 141 p refs  
 (Contract NAS3-17866)  
 (NASA-CR-2628, PWA-5296) Avail NTIS HC A07/MF A01  
 CSCL 01B

The static aerodynamic and acoustic characteristics of duct-burning turbofan (DBTF) exhaust nozzles are established. Scale models, having a total area equivalent to a 0.127 m diameter convergent nozzle, simulating unsuppressed coannular nozzles and mechanically suppressed nozzles with and without ejectors (hardwall and acoustically treated) were tested in a quiescent environment. The ratio of fan to primary area was varied from 0.75 to 1.2. Far field acoustic data, perceived noise levels, and thrust measurements were obtained for 417 test conditions. Pressure ratios were varied from 1.3 to 4.1 in the fan stream and from 1.53 to 2.5 in the primary stream. Total temperature varied from 395 to 1090 K in both streams. Jet noise reductions relative to synthesized prediction from 8 PNdB (with the unsuppressed coannular nozzle) to 15 PNdB (with a mechanically suppressed configuration) were observed at conditions typical of engines being considered under the Advanced Supersonic Technology program. The inherent suppression characteristic of the unsuppressed coannular nozzle is related to the rapid mixing in the jet wake caused by the velocity profiles associated with the DBTF. Since this can be achieved without a mechanical suppressor, significant reductions in aircraft weight or noise footprint can be realized.

Author

**N77-18022\*** General Electric Co., Philadelphia, Pa. Aircraft Engine Group  
**COANNULAR PLUG NOZZLE NOISE REDUCTION AND IMPACT OF EXHAUST SYSTEM DESIGNS** c07  
 Robert Lee In NASA Langley Res Center Proc of the SCAR Conf, Pt 2, 1976 20 p (For primary document see N77-18019 09-01)  
 (Contracts NAS3-18008, NAS3-19777; DOT-OST-30034)  
 Avail NTIS HC A23/MF A01 CSCL 20A

Reducing the noise generated by high velocity jets has confronted engine designers and acoustics workers alike for the past fifteen years. Some of the jet noise suppressor configurations that are investigated are shown. With the exception of the early CJ-805 daisy suppressor nozzle which found successful application on the Convair 990 airplane, the others were developmental hardware at different stages of the effort in the past eight years - all aiming at potential supersonic cruise aircraft applications. Some significant progress was made as the result of work supported by NASA and FAA in the past two to three years. This work pertains to the concept demonstration and scale model testing of coannular plug nozzles with inverted velocity profile, and to the preliminary study of its application to advanced variable cycle engines (VCE) appropriate for supersonic cruise aircraft.

Author

## 02 AERODYNAMICS

Includes aerodynamics of bodies, combinations, wings, rotors, and control surfaces; and internal flow in ducts and turbomachinery.

For related information see also 34 *Fluid Mechanics and Heat Transfer*.

**N77-11004\*** National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio.

### PERFORMANCE AND BOUNDARY-LAYER EVALUATION OF A SONIC INLET

James F. Schmidt and Robert S. Ruggeri Washington Nov. 1976 57 p refs  
(NASA-TN-D-8340; E-8579) Avail: NTIS HC A04/MF A01 CSDL 01A

Tests were conducted to determine the boundary layer characteristics and aerodynamic performance of a radial vane sonic inlet with a length/diameter ratio of 1 for several vane configurations. The sonic inlet was designed with a slight wavy wall type of diffuser geometry, which permits operation at high inlet Mach numbers (sufficiently high for good noise suppression) without boundary layer flow separation and with good total pressure recovery. A new method for evaluating the turbulent boundary layer was developed to separate the boundary layer from the inviscid core flow, which is characterized by a total pressure variation from hub to tip, and to determine the experimental boundary layer parameters. Author

**N77-11007\*** National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio.

### TWO-DIMENSIONAL COLD-AIR CASCADE STUDY OF A FILM-COOLED TURBINE STATOR BLADE. 3: EFFECT OF HOLE SIZE ON SINGLE-ROW AND MULTIROW EJECTION

Harman W. Prust, Jr. and Thomas P. Moffitt Washington Oct. 1976 33 p refs  
(NASA-TM-X-3442; E-8720) Avail: NTIS HC A03/MF A01 CSDL 20D

The effect of coolant discharge on the aerodynamic performance of a film cooled turbine stator blade was determined. The blade had the same number, location, and injection angle of coolant holes, but the coolant hole diameters were one half that of a previously investigated blade. Otherwise the blades were the same. Tests with discharge from individual coolant rows and multiple coolant rows, including full film discharge are studied. The results of the blade with smaller holes are reported and compared with the blades with larger holes. Author

**N77-11008\*** National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio.

### PERFORMANCE OF 1.15-PRESSURE-RATIO FAN STAGE AT SEVERAL ROTOR BLADE SETTING ANGLES WITH REVERSE FLOW

George Kovich and Royce D. Moore Washington Nov. 1976 91 p refs  
(NASA-TM-X-3451; E-8571) Avail: NTIS HC A05/MF A01 CSDL 21E

A 51 cm diameter low pressure ratio fan stage was tested in reverse flow. Survey flow data were taken over the range of rotative speed from 50 percent to 100 percent design speed at several rotor blade setting angles through both flat and feather pitch. Normal flow design values of pressure ratio and weight flow were 1.15 and 29.9 kg/sec with a rotor tip speed of 243.6 m/sec. The maximum thrust in reverse flow was 52.5 percent of design thrust in normal flow. Author

**N77-11991\*** National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio.

### INLET TOTAL PRESSURE LOSS DUE TO ACOUSTIC WALL TREATMENT

Brent A. Miller [1977] 16 p refs Proposed for presentation at 15th Aerospace Sci. Meeting, Los Angeles, 24-26 Jan. 1977;

sponsored by AIAA

(NASA-TM-X-73559; E-8946) Avail: NTIS HC A02/MF A01 CSDL 01A

The effect of diffuser wall acoustic treatment on inlet total pressure loss was experimentally determined. Data were obtained by testing an inlet model with 10 different acoustically treated diffusers differing only in the design of the Helmholtz resonator acoustic treatment. Tests were conducted in a wind tunnel at forward velocities to 41 meters per second for inlet throat Mach numbers of .5 to .8 and angles of attack as high as 50 degrees. Results indicate a pressure loss penalty due to acoustic treatment that increases linearly with the porosity of the acoustic facing sheet. For a surface porosity of 14 percent the total pressure loss was 21 percent greater than that for an untreated inlet. Author

**N77-12000\*** National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio.

### COLD-AIR PERFORMANCE OF A TIP TURBINE DESIGNED TO DRIVE A LIFT FAN. 1: BASELINE PERFORMANCE

Jeffrey E. Haas, Milton G. Kofsky, Glen M. Hotz, and Samuel M. Futral, Jr. Washington Dec. 1976 25 p refs Prepared in cooperation with Army Air Mobility R and D Lab., Cleveland (NASA-TM-X-3452; E-8754) Avail: NTIS HC A02/MF A01 CSDL 21E

Full admission baseline performance was obtained for a 0.4 linear scale of the LF460 lift fan turbine over a range of speeds and pressure ratios without leakage air. These cold-air tests covered a range of speeds from 40 to 140 percent of design equivalent speed and a range of scroll inlet to diffuser exit static pressure ratios from 2.0 to 4.2. Results are presented in terms of specific work, torque, mass flow, efficiency, and total pressure drop. Author

**N77-16991\*** National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio.

### ESTIMATE OF CONJUGATE GAMMA AND GAMMA PRIME COMPOSITIONS IN NI-BASE SUPERALLOYS

Robert L. Dreshfield 1977 31 p refs Presented at Workshop on Applications of Phase Diagrams in Metallurgy and Ceramics, Gaithersburg, Md., 10-12 Jan. 1977; sponsored by NBS

(NASA-TM-X-73576; E-9033) Avail: NTIS HC A03/MF A01 CSDL 11F

Approaches for estimating the composition of the matrix phase of alloys from the melt composition are reviewed. The first method is based on assigning essentially fixed stoichiometry to precipitating phases and is typified by PHACOMP. The second method uses analytical geometry to interpret phase diagrams and is applicable to a two-phase region of a six-component Ni-base system. The geometric method is also applicable to commercial Ni-base superalloys. Author

**DATA SUMMARY** Chemical and phase compositions of nickel-base superalloys; variables include weight percent, atomic percent, 6 figures and 12 tables include numeric data.

**N77-16992\*** National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio.

### EFFECTS OF TIP CLEARANCE ON OVERALL PERFORMANCE OF TRANSONIC FAN STAGE WITH AND WITHOUT CASING TREATMENT

Royce D. Moore and Walter M. Osborn Feb. 1977 26 p refs  
(NASA-TM-X-3479; E-8945) Avail: NTIS HC A03/MF A01 CSDL 01A

The overall performance of a transonic fan stage is presented for various tip clearances, with and without casing treatment. The stage was tested with a solid casing, and with open skewed slots and closed skewed slots in the casing over the rotor blade tips. Four nominal nonrotating rotor blade tip clearances from 0.061 to 0.178 centimeter were used. For all three casings, the pressure ratio and efficiency decreased with increasing tip clearance. The stall margin for a given casing also decreased with increasing clearance. At design speed and a given tip clearance, the highest stall margin was obtained with the open slot

casing, and the lowest stall margin was obtained with the solid casing.

Author

**DATA SUMMARY:** Effects of solid casing and porous casing on rotor blade tip clearances from 0.061 to 0.178 cm and on operating range (rotative speeds from 50 to 100 percent of design speed) of axial flow rotor; variables include rotative speed, airflow kg/sec, pressure ratio, temperature ratio, adiabatic efficiency, stall margin, flow path geometry; 6 figures and 3 tables include numeric data.

**N77-18998\*** National Aeronautics and Space Administration  
Lewis Research Center, Cleveland, Ohio.

**EFFECTS OF RESET STATORS AND A ROTATING, GROOVED STATOR HUB ON PERFORMANCE OF A 1.92-PRESSURE-RATIO COMPRESSOR STAGE**

George W. Lewis, Donald C. Urasek, and Lonnie Reid Washington  
Feb. 1977 93 p refs

(NASA-TM-X-3472, E-7947) Avail: NTIS HC A05/MF A01  
CSCL 01A

The overall performance and blade-element performance of a transonic fan stage are presented for two modified test configurations and are compared with the unmodified stage. Tests were conducted with reset stators 2 deg open and reset stators with a rotating grooved stator hub. Detailed radial and circumferential (behind stator) surveys of the flow conditions were made over the stable operating range at rotative speeds of 70, 90, and 100 percent of design speed. Reset stator blade tests indicated a small increase in stage efficiency, pressure ratio, and maximum weight flow at each speed. Performance with reset stators and a rotating, grooved stator hub resulted in an additional increase in stage efficiency and pressure ratio at all speeds. The rotating grooved stator hub reduced hub losses considerably.

Author

**DATA SUMMARY:** Improved stage efficiency at 70 and 90 percent of design speed for transonic fan with stator modifications, the variables are design blade element parameters, design speed, blade edges, pressure ratio, equivalent weight flow (kg/sec), diffusion factor, loss coefficient, meridional velocity ratio, and suction-surface incidence angle; 10 figures and 11 tables include numeric data.

**N77-18050\*** National Aeronautics and Space Administration  
Lewis Research Center, Cleveland, Ohio.

**COLD AIR PERFORMANCE OF A TIP TURBINE DESIGNED TO DRIVE A LIFT FAN. 2: PARTIAL ADMISSION**

Jeffrey E. Haas, Milton Koeske, Glen M. Hotz, and Samuel M. Futral, Jr. Washington Feb. 1977 27 p refs Prepared in cooperation with Army Air Mobility Res and Develop Lab, Cleveland.

(NASA-TM-X-3481, E-8914) Avail: NTIS HC A03/MF A01  
CSCL 01A

Partial admission performance was obtained for a 0.4 linear scale version of the LF460 lift fan turbine over a range of speed from 40 to 140 percent of design equivalent speed and a range of scroll inlet total to diffuser exit static pressure ratio from 2.2 to 5.0. The investigation was conducted in two parts, with each part using a different side of the turbine scroll to simulate loss of a gas generator. Each side had an arc of admission of 180. Results are presented in terms of specific work, torque, mass flow, and efficiency.

Author

**DATA SUMMARY:** Partial admission performance of 0.4 linear scale lift fan turbine over a range of speed and pressure ratio, variables include mass flow rate, pressure ratio, equivalent torque, design equivalent speed, stator inlet and rotor exit flow conditions, flow velocity, flow angle, and equivalent specific work; 12 figures and 2 tables.

**N77-18051\*** National Aeronautics and Space Administration,  
Lewis Research Center, Cleveland, Ohio.

**ACOUSTIC AND AERODYNAMIC PERFORMANCE OF A VARIABLE-PITCH 1.83-METER-(6-FT) DIAMETER 1.20-PRESSURE-RATIO FAN STAGE (QF-9)**

Frederick W. Glaser, Richard P. Woodward, and James G. Lucas  
Washington Feb. 1977 67 p refs

(NASA-TN-D-8402, E-8837) Avail: NTIS HC A04/MF A01  
CSCL 01A

Far field noise data and related aerodynamic performance are presented for a variable pitch fan stage having characteristics suitable for low noise, STOL engine application. However, no acoustic suppression material was used in the flow passages. The fan was externally driven by an electric motor. Tests were made at several forward thrust rotor blade pitch angles and one for reverse thrust. Fan speed was varied from 60 to 120 percent of takeoff (design) speed, and exhaust nozzles having areas 92 to 105 percent of design were tested. The fan noise level was at a minimum at the design rotor blade pitch angles of 64 deg for takeoff thrust and at 57 deg for approach (50 percent takeoff thrust). Perceived noise along a 152.4-m sideline reached 100.1 PNdB for the takeoff (design) configuration for a stage pressure ratio of 1.17 and thrust of 57,600 N. For reverse thrust the PNL values were 4 to 5 PNdB above the takeoff values at comparable fan speeds.

Author

**DATA SUMMARY:** Sound pressure level, sound power level, and perceived noise level of low noise STOL engine fan stage; the variables include stage total pressure ratio, rotor tip speed, inlet weight flow, rotor blade pitch angle, design nozzle area (sq m), Mach number, stall line, fan speed, thrust load, sound pressure level (dB), sound power level (dB), perceived noise (PNdB), and stage adiabatic efficiency; 39 figures and 4 tables.

**N77-18056\*** National Aeronautics and Space Administration  
Lewis Research Center, Cleveland, Ohio.

**EFFECT OF CASING TREATMENT OF OVERALL PERFORMANCE OF AXIAL-FLOW TRANSONIC FAN STAGE WITH PRESSURE RATIO OF 1.75 AND TIP SOLIDITY OF 1.5**

Walter M. Osborn and Royce D. Moore Washington Feb. 1977 23 p refs

(NASA-TM-X-3477, E-8488) Avail: NTIS HC A02/MF A01  
CSCL 01A

The effect of a number of casing treatments on the overall performance of a 1.75-pressure-ratio, 423-m/sec-tip-speed fan stage was evaluated. The skewed slot configuration with short-open slots over the midportion of the rotor had a stall margin of 23.5 percent, while the solid casing had a stall margin of 15.0 percent. The skewed slot configuration with long open slots extending ahead of and over portion of rotor displaced the stall line to the lowest flow at all speeds tested. At design speed, the peak efficiency for the long, forward open slots was 1 point less than that for the short midopen slots and 3 points less than that for the solid casing.

Author

**DATA SUMMARY:** The effectiveness of a solid casing, a teardrop casing, and eight variations of a skewed slot casing based on the increase in stall margin and on the ability to displace the stall line to lower flows, variables include percent speed, flow, pressure ratio, temperature ratio, adiabatic efficiency, stall margin, peak efficiency, radius, and axial distance; 3 figures and 3 tables include numeric data.

**N77-20031\*#** National Aeronautics and Space Administration  
Lewis Research Center, Cleveland, Ohio.

**PERFORMANCE OF LOW-PRESSURE-RATIO FAN STAGE AT TWO OFF-DESIGN BLADE SETTING ANGLES**

George Kovich, Edward R. Tysl, and Royce D. Moore Washington  
Mar. 1977 90 p

(NASA-TM-X-3447; E-8578) Avail. NTIS HC A05/MF A01  
CSCL 01A

The overall and blade-element performance of a low pressure ratio, low tip speed fan stage at design speed is presented for two off-design rotor blade angle settings. The rotor design tip speed is 243.8 m/sec and weight flow per unit annulus area is 175.8 kg/sec. Design weight flow and pressure ratio are 29.9 kg/sec and 1.151, respectively.

Author

**N77-21049\*#** National Aeronautics and Space Administration  
Lewis Research Center, Cleveland, Ohio

**ANALYSIS OF INTERNAL FLOW OF J85-13 MULTISTAGE COMPRESSOR**

Roy D. Hager Apr. 1977 20 p refs

(NASA-TM-X-3513; E-8493) Avail. NTIS HC A02/MF A01  
CSCL 01A

Interstage data recorded on a J85-13 engine were used to analyze the internal flow of the compressor. Measured pressures and temperatures were used as input to a streamline analysis program to calculate the velocity diagrams at the inlet and outlet of each blade row. From the velocity diagrams and blade geometry, selected blade-element performance parameters were calculated. From the detailed analysis it is concluded that the compressor is probably hub critical (stall initiates at the hub) in the latter stages for the design speed conditions. As a result, the casing treatment over the blade tips has little or no effect on stall margin at design speed. Radial inlet distortion did not appear to change the flow in the stages that control stall because of the rapid attenuation of the distortion within the compressor.

Author

**N77-21051\*#** National Aeronautics and Space Administration  
Lewis Research Center, Cleveland, Ohio

**ACOUSTIC AND AERODYNAMIC PERFORMANCE OF A 1.5-PRESSURE-RATIO, 1.83-METER (6 FT) DIAMETER FAN STAGE FOR TURBOFAN ENGINES (QF-2)**

Richard P. Woodward, James G. Lucas, and Joseph R. Balombin  
Washington Apr. 1977 57 p refs

(NASA-TM-X-3521; E-8968) Avail. NTIS HC A04/MF A01  
CSCL 21E

The fan was externally driven by an electric motor. Design features for low-noise generation included the elimination of inlet guide vanes, long axial spacing between the rotor and stator blade rows, and the selection of blade-vane numbers to achieve duct-mode cutoff. The fan QF-2 results were compared with those of another full-scale fan having essentially identical aerodynamic design except for nozzle geometry and the direction of rotation. The fan QF-2 aerodynamic results were also compared with those obtained from a 50.8 cm rotor-tip-diameter model of the reverse rotation fan QF-2 design. Differences in nozzle geometry other than exit area significantly affected the comparison of the results of the full-scale fans.

Author

**N77-22046\*#** National Aeronautics and Space Administration  
Lewis Research Center, Cleveland, Ohio

**ACOUSTIC TESTS OF AUGMENTOR WING MODEL**

Jack H. Goodykoontz Washington Apr. 1977 56 p refs

(NASA-TM-X-3519; E-8923) Avail. NTIS HC A04/MF A01  
CSCL 20A

Acoustic and aerodynamic data were obtained for a full-scale section of an augmentor wing. Features of the design included a single-row, multielement nozzle array and acoustically tuned panels placed on the interior surfaces of the augmentor. When the data were extrapolated to a 91,000-kilogram aircraft, the calculated sideline perceived noise levels were approximately the same for either the takeoff or approach condition.

Author

**N77-25084\*#** National Aeronautics and Space Administration  
Lewis Research Center, Cleveland, Ohio

**EXPERIMENTAL PERFORMANCE OF A 16.10-CENTIMETER-TIP-DIAMETER SWEEPBACK CENTRIFUGAL COMPRESSOR DESIGNED FOR A 6:1 PRESSURE RATIO**

Hugh A. Klassen, Jerry R. Wood, and Lawrence F. Schumann  
Jun. 1977 31 p refs

(NASA-TM-X-3552; E-9074) Avail. NTIS HC A03/MF A01  
CSCL 21E

A backswapt impeller with design mass flow rate of 1.033 kg/sec was tested with both a vaned diffuser and a vaneless diffuser to establish stage and impeller characteristics. Design stage pressure ratio of 5.91 was attained at a flow slightly lower than the design value. Flow range at design speed was 6 percent of choking flow. Impeller axial tip clearance at design speed was varied to determine effect on stage and impeller performance.

Author

**N77-25091\*#** National Aeronautics and Space Administration  
Lewis Research Center, Cleveland, Ohio

**CHARACTERISTICS OF RANDOM INLET PRESSURE FLUCTUATIONS DURING FLIGHTS OF F-111A AIRPLANE**

William G. Costakis Washington May 1977 36 p refs

(NASA-TM-X-3540; E-9037) Avail. NTIS HC A03/MF A01  
CSCL 01A

Compressor face dynamic total pressures from four F-111 flights were analyzed. Statistics of the nonstationary data were investigated by analyzing the data in a quasi-stationary manner. Changes in the character of the dynamic signal are investigated as functions of flight conditions, time in flight, and location at the compressor face. The results, which are presented in the form of rms values, histograms, and power spectrum plots, show that the shape of the power spectra remains relatively flat while the histograms have an approximate normal distribution.

Author

**N77-25092\*#** National Aeronautics and Space Administration  
Lewis Research Center, Cleveland, Ohio

**CORRELATION OF PART-SPAN DAMPER LOSSES THROUGH TRANSONIC ROTORS OPERATING NEAR DESIGN POINT**

William B. Roberts (Notre Dame Univ. Ind.) Washington Jun. 1977 23 p refs

(NASA-TM-X-3542; E-9068) Avail. NTIS HC A02/MF A01  
CSCL 01A

The design-point losses caused by part-span dampers (PSD) were correlated for 21 transonic axial flow fan rotors that had tip speeds varying from 350 to 488 meters per second and design pressure ratios of 1.5 to 2.0. For these rotors a correlation using mean inlet Mach number at the damper location, along with relevant geometric and aerodynamic loading parameters, predicts the variation of total pressure loss coefficient in the region of the damper to a good approximation.

Author

**N77-27089\*#** National Aeronautics and Space Administration  
Lewis Research Center, Cleveland, Ohio

**FORTAN PROGRAM FOR CALCULATING LEADING AND TRAILING-EDGE GEOMETRY OF TURBOMACHINE BLADES**

Lawrence F. Schumann Jun. 1977 22 p refs

(NASA-TM-X-73679; E-9211) Avail. NTIS HC A02/MF A01  
CSCL 01A

A FORTRAN IV program which calculates leading- and trailing-edge circle radii, tangency angles on the leading- and trailing-edge circles, and stagger angles of turbomachinery blade sections using only spline points defining the blade surfaces is described. The program shifts the origin of the blade coordinates to the leading edge of the blade. Required input includes (m, theta) coordinates of a sufficient number of spline points to adequately define the two surfaces of the blade. Other required input are the radii from the axis of rotation of the leading- and trailing-edges. The output from this program is used directly as



the geometrical input for a NASA developed program for calculating transonic velocities on a blade-to-blade stream surface of a turbomachine. The program is used for axial, radial, and mixed flow turbomachine blades. Author

**N77-28074\*** National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio.  
**PERFORMANCE AT MACH 3.52 OF A MACH 2.5 ALL EXTERNAL-COMPRESSION, TWO DIMENSIONAL INLET**  
Robert W. Cubbison Jun. 1977 43 p  
(NASA-TM-73696; E-9235) Avail NTIS HC A03/MF A01 CSCL 01A

A quick-look test was conducted in the 10- by 10-foot supersonic wind tunnel to provide some qualitative information on operating a low Mach number design inlet in a highly oversped condition. The model which is a two-dimensional, three-ramp, all-external-compression inlet designed to match a J-85 turbojet engine at Mach 2.5 was run at Mach 3.52 and zero angle-of-attack and yaw. Results are presented showing the effect of external ramp angle combinations, diffuser ramp position, and amount of bleed. Author

**N77-28087\*** National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio.  
**COMPARISON OF JET MACH NUMBER DECAY DATA WITH A CORRELATION AND JET SPREADING CONTOURS FOR A LARGE VARIETY OF NOZZLES**  
Donald E. Groesbeck, Ronald G. Huff, and Uwe H. VonGlahn Washington Jun. 1977 300 p refs  
(NASA-TN-D-8423; E-8561) Avail NTIS HC A13/MF A01 CSCL 01A

Small-scale circular, noncircular, single- and multi-element nozzles with flow areas as large as 122 sq cm were tested with cold airflow at exit Mach numbers from 0.28 to 1.15. The effects of multi-element nozzle shape and element spacing on jet Mach number decay were studied in an effort to reduce the noise caused by jet impingement on externally blown flap (EBF) STOL aircraft. The jet Mach number decay data are well represented by empirical relations. Jet spreading and Mach number decay contours are presented for all configurations tested. Author

**N77-28088\*** National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio.  
**AERODYNAMIC PERFORMANCE OF 0.4066-SCALE MODEL OF JT8D REFAN STAGE WITH S-DUCT INLET**  
Royce D. Moore, George Kovich, and George W. Lewis, Jr Washington May 1977 296 p refs  
(NASA-TN-D-8458; E-8268) Avail NTIS HC A13/MF A01 CSCL 01A

A scale model of the JT8D refan stage was tested with a scale model of the S-duct inlet design for the refanned Boeing 727 center engine. Detailed survey data of pressures, temperatures, and flow angles were obtained over a range of flows at speeds from 70 to 97 percent of design speed. Two S-duct configurations were tested; one with a bellmouth inlet and the other with a flight lip inlet. The results indicated that the overall performance was essentially unaffected by the distortion generated by the S-duct inlet. The stall weight flow increased by less than 0.5 kg/sec (approximately 1.5% of design flow) with the S-duct inlet compared with that obtained with uniform flow. The detailed measurements indicated that the inlet guide vane (IGV) significantly reduced circumferential variations. For example, the flow angles ahead of the IGV were positive in the right half of the inlet and negative in the left half. Behind the IGV, the flow angles tended to be more uniform circumferentially. Author

**N77-29099\*** National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio.  
**REVISED FORTRAN PROGRAM FOR CALCULATING VELOCITIES AND STREAMLINES ON THE HUB-SHROUD MIDCHANNEL STREAM SURFACE OF AN AXIAL, RADIAL, OR MIXED-FLOW TURBOMACHINE OR ANNULAR DUCT. 2: PROGRAMMER'S MANUAL**  
Theodore Katsanis and William D. McNally Washington Jul 1977 232 p refs Revised  
(NASA-TN-D-8431; E-8969) Avail NTIS HC A11/MF A01 CSCL 01A

A FORTRAN IV computer program has been developed that obtains a detailed subsonic or shock free transonic flow solution on the hub-shroud midchannel stream surface of a turbomachine. The blade row may be fixed or rotating, and the blades may be twisted and leaned. Flow may be axial, mixed, or radial. Upstream and downstream flow variables may vary from hub to shroud, and provisions are made to correct for loss of stagnation pressure. The results include velocities, streamlines, and flow angles on the stream surface and approximate blade surface velocities. Author

**N77-30089\*** National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio.  
**COLD AIR PERFORMANCE OF A 12.766-CENTIMETER-TIP-DIAMETER AXIAL-FLOW COOLED TURBINE. 2: EFFECT OF AIR EJECTION ON TURBINE PERFORMANCE**  
Jeffrey E. Haas and Milton G. Kofskey Aug. 1977 37 p refs  
Prepared in cooperation with Army Air Mobility Res. and Develop Lab., Cleveland  
(NASA-TP-1018) Avail NTIS HC A03/MF A01 CSCL 21E

An air cooled version of a single-stage, axial flow turbine was investigated to determine aerodynamic performance with and without air ejection from the stator and rotor blades surfaces to simulate the effect of cooling air discharge. Air ejection rate was varied from 0 to 10 percent of turbine mass flow for both the stator and the rotor. A primary-to-air ejection temperature ratio of about 1 was maintained. Author

**N77-32082\*** National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio.  
**COLD-AIR PERFORMANCE OF A 12.766-CENTIMETER-TIP-DIAMETER AXIAL-FLOW COOLED TURBINE. 3: EFFECT OF ROTOR TIP CLEARANCE ON OVERALL PERFORMANCE OF A SOLID BLADE CONFIGURATION**  
Jeffrey Haas (Army Air Mobility Research and Development Lab., Cleveland, Ohio) and Milton G. Kofskey Sep. 1977 24 p refs  
(NASA-TP-1032; E-9181) Avail NTIS HC A02/MF A01 CSCL 01A

Two tip clearance configurations, one with a recess in the casing and the other with a reduced rotor blade height, were investigated at design equivalent speed over a range of tip clearance from about 2.0 to 5.0 percent of the stator blade height. The optimum configuration with a recess in the casing was the one where the rotor tip diameter was equal to the stator tip diameter (zero blade extension). For this configuration there was an approximate 7.5 percent decrease in total efficiency for an increase in tip clearance of 1 percent of stator blade height. For the reduced blade height configurations there was an approximate 2.0 percent decrease in total efficiency for an increase in tip clearance of 1 percent of stator blade height. Author

**N77-33107\*** National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio.  
**NONLINEAR AEROELASTIC EQUATIONS FOR COMBINED FLAPWISE BENDING, CHORDWISE BENDING, TORSION, AND EXTENSION OF TWISTED NONUNIFORM ROTOR BLADES IN FORWARD FLIGHT**  
Krishna Rao V. Kaza and Raymond G. Kvaternik (NASA Langley Res. Center) Aug. 1977 111 p refs  
(NASA-TM-74059) Avail NTIS HC A06/MF A01 CSCL 01A  
Second-degree nonlinear aeroelastic equations were developed using Hamilton's principle. The implications of the slender

beam approximation as applied to the derivation of the second-degree nonlinear equations of motion are discussed and a mathematical ordering scheme which is compatible with the assumption of a slender beam is introduced. The blade aerodynamic loading was obtained from strip theory based on a quasi-steady approximation of two dimensional, incompressible unsteady airfoil theory. The equations were compared with several of those existing in the literature and the results are discussed. Author

**A77-13729 \*** # Skin friction on a flat perforated acoustic liner. D. R. Boldman (NASA, Lewis Research Center, Physical Sciences Div., Cleveland, Ohio) and P. F. Brinich, *AIAA Journal*, vol. 14, Nov. 1976, p. 1656-1659. 7 refs.

The report concerns the measurement of friction coefficients of a typical perforated acoustic liner installed in the side of a wind tunnel. The results are compared with measured friction coefficients of a smooth hard wall for the same mean flow velocities in a wind tunnel. At a velocity of 61 m/sec, an increase in the local skin coefficient of only a few percent was observed, but at the highest velocity of 213 m/sec an increase of about 20% was obtained. This velocity is a realistic velocity for turbo-machinery components utilizing such liners, so a loss in performance is to be expected. Some tests were also performed to see if changes in the mean boundary layer induced by imposed noise would result in friction increase, but only at low velocity levels was such an increase in friction noted.

P.T.H.

**A77-15037 \*** Improved interactive calculation procedure for supersonic flows. Y. Tassa, E. Reshotko (Case-Western Reserve University, Cleveland, Ohio), and B. H. Anderson (NASA, Lewis Research Center, Cleveland, Ohio). *Israel Annual Conference on Aviation and Astronautics, 18th, Tel Aviv and Haifa, Israel, May 19, 20, 1976.* *Israel Journal of Technology*, vol. 14, no. 1-2, 1976, p. 94-107. 9 refs.

An interactive numerical procedure has been developed for supersonic viscous flows (either two-dimensional or axisymmetric configurations). The flow field is divided into two regions: (1) an inner region which is highly viscous and mostly subsonic, and (2) an outer region where the flow is supersonic and in which viscous effects are small, but not negligible. This paper presents a detailed description of: I. Outer Region - numerical solution obtained by applying the method of characteristics to a system of equations which includes viscous and conduction transport terms only normal to the streamlines; II. Inner Region - treated by a system of equations of the boundary-layer type that includes higher order effects, such as longitudinal and transverse curvature and normal pressure gradients (equations are coupled and solved simultaneously in physical coordinates, using an implicit finite-difference scheme); III. Interactive Procedure - in the interaction mode, the two regions are coupled iteratively along a matching line, where the Mach number is of the order of 1.2. (Author)

**A77-19802 \*** # Acoustic signatures of a model fan in the NASA-Lewis anechoic wind tunnel. D. A. Dietrich, M. F. Heidmann, and J. M. Fott (NASA, Lewis Research Center, Cleveland, Ohio). *American Institute of Aeronautics and Astronautics, Aerospace Sciences Meeting, 15th, Los Angeles, Calif., Jan. 24-26, 1977. Paper 77-59.* 11 p. 35 refs.

One-third octave band and narrowband spectra and continuous directivity patterns radiated from an inlet are presented over ranges of fan operating conditions, tunnel velocity, and angle of attack. Tunnel flow markedly reduced the unsteadiness and level of the blade passage tone, revealed the cut-off design feature of the blade passage tone, and exposed a lobular directivity pattern for the second harmonic tone. The full effects of tunnel flow are shown to be complete above a tunnel velocity of 20 meters/second. The acoustic signatures are also shown to be strongly affected by fan rotational speed, fan blade loading, and inlet angle of attack. (Author)

**DATA SUMMARY:** Narrowband sound pressure levels were studied for airflow velocities of 0-50 m/s and one-third octave band sound

pressure levels were studied for microphone angles from the fan axis in the range 20-120 degrees; variables are fan total pressure ratio, fan corrected mass flow, airflow velocity, microphone angle from fan axis, design rotational speed, frequency, fan rotational speed, one-third octave band sound pressure, and narrowband sound pressure; 10 figures include numeric data.

**A77-19983 \*** Prediction of laminar and turbulent boundary layer flow separation in VISTOL engine inlets. D. C. Chou, R. W. Luidens, and N. O. Stockman (NASA, Lewis Research Center, Cleveland, Ohio). *American Institute of Aeronautics and Astronautics, Aerospace Sciences Meeting, 15th, Los Angeles, Calif., Jan. 24-26, 1977. Paper 77-144.* 17 p. 8 refs.

The paper provides a theoretical description of the development of the boundary layer on the lip and diffuser surface of a subsonic inlet at arbitrary operating conditions of mass flow rate, freestream velocity and incidence angle. Both laminar separation on the lip and turbulent separation in the diffuser are discussed. The agreement of the theoretical results with model experimental data illustrates the capability of the theory to predict separation. The effects of throat Mach number, inlet size, and surface roughness on boundary layer development and separation are illustrated. (Author)

**DATA SUMMARY:** The effects of incidence angle on flow separation at the windward side and the effects of average throat Mach number on the location of separation and local separation conditions also on the windward side are studied; variables are incidence angle, average throat Mach number, local skin friction coefficient, dimensionless surface distance from highlight, and shape factor; 11 figures include numeric data.

**A77-41980 \*** # Use of experimental separation limits in the theoretical design of V/STOL inlets. M. A. Boles (Indiana Institute of Technology, Fort Wayne, Ind.) and N. O. Stockman (NASA, Lewis Research Center, Wind Tunnel and Flight Div., Cleveland, Ohio). *American Institute of Aeronautics and Astronautics and Society of Automotive Engineers, Propulsion Conference, 13th, Orlando, Fla., July 11-13, 1977. AIAA Paper 77-878.* 24 p. 9 refs.

Experimental data from several model inlets have been used to generate two parameters which are related to the limit of operation for inlet flow separation. One parameter, called the diffusion ratio, is the ratio of the peak velocity on the inlet surface to the velocity at the diffuser exit and is related to the boundary layer separation at low throat Mach numbers. The other parameter, the peak Mach number on the inlet surface, is related to the separation at high throat Mach numbers. These parameters are easily calculated from potential flow solutions and thus can be used as a design tool in screening proposed inlet geometries. Any of the geometric design variables can be analyzed by this technique; but, this paper is restricted to the consideration of the internal lip contraction ratio. An illustrative example of an application to an inlet design study for a tilt nacelle VTOL airplane is presented. The study will show what value of contraction ratio is required to meet the operating requirements yet allow the inlet to remain free of separation as indicated by the two separation parameters. (Author)

**A77-28072 \*** # Illinois Univ. Urbana-Champaign  
**VISCID-INVISCID INTERACTION ASSOCIATED WITH INCOMPRESSIBLE FLOW PAST WEDGES AT HIGH REYNOLDS NUMBER. Final Report**  
N. R. Wapinski and W. L. Chow Aug 1977 142 p refs  
(Grant NGL-14-005-140)  
(NASA-CR-135246; ME-TR-395-4) Avail: NTIS  
HC A07/MF A01 CSCL 01A

An analytical method is suggested for the study of the viscid inviscid interaction associated with incompressible flow past wedges with arbitrary angles. It is shown that the determination of the nearly constant pressure (base pressure) prevailing within the near wake is really the heart of the problem, and the pressure can only be established from these interactive considerations. The basic free streamline flow field is established through two discrete parameters which adequately describe the inviscid

flow around the body and the wake. The viscous flow processes such as the boundary layer buildup, turbulent jet mixing, and recompression are individually analyzed and attached to the inviscid flow in the sense of the boundary layer concept. The interaction between the viscous and inviscid streams is properly displayed by the fact that the aforementioned discrete parameters needed for the inviscid flow are determined by the viscous flow condition at the point of reattachment. It is found that the reattachment point behaves as a saddle point singularity for the system of equations describing the recompressive viscous flow processes, and this behavior is exploited for the establishment of the overall flow field. Detailed results such as the base pressure, pressure distributions on the wedge, and the geometry of the wake are determined as functions of the wedge angle. Author

**N77-31086\*** Boeing Co., Seattle, Wash. Military Airplane Development.

**OPERATING CHARACTERISTICS OF AN INLET MODEL TESTED WITH A 0.6m POWERED FAN AT HIGH ANGLES OF ATTACK**

J. L. Koncsek and R. J. Shaw. Sep. 1977. 60 p. refs. Prepared in cooperation with NASA. Lewis Res. Center (Contract NAS3-20597)

(NASA-CR-135270. D180-20798-11 Avail NTIS HC A04/MF A01 CSCL 01A

An inlet model designed for high angle of attack capability coupled to a 508 m tip diameter turbofan simulator, was tested in the NASA-Lewis Research Center's 9-by 15-ft low speed wind tunnel. The test variables were tunnel velocity, 0 to 75 m/s; inlet angle of attack, 0 to 120 deg; and fan face corrected airflow per unit area, 75 to 200 kg/s sqm. The inlet flow separation boundaries, the fan face total pressure recovery and distortion characteristics, and the fan blade vibratory stresses were determined. The recovery, distortion, and stress levels showed no abrupt changes at the onset of separation, but became gradually more unfavorable as the size and intensity of the separation increased as induced by increasingly severe operating conditions. Performance characteristics for a large scale model of the inlet were estimated from these test results. Author

**N77-33113\*** Hamilton Standard, Windsor Locks, Conn. **STUDY OF NOISE AND INFLOW DISTORTION SOURCES IN THE NASA QF-18 FAN USING MEASURED BLADE AND VANE PRESSURES. Final Report**

Donald B. Hanson. Washington: NASA. Sep. 1977. 85 p. refs. (Contract NAS3 19749)

(NASA-CR-2899) Avail NTIS HC A05/MF A01 CSCL 20A

Pressure transducers were installed on the blades and vanes of QF-18, a transonic-tip-speed fan from the NASA Quiet Fan Program which was tested on the outdoor quiet fan test facility at NASA-Lewis. Signals from the transducers and from far field microphones were analyzed to determine sources of nonuniform inflow and noise. The nonuniform inflow was mostly unsteady with roughly equal contributions from atmospheric turbulence and rig interference. The rig interference was largest at the bottom and appeared to be generated by the support structure which was located behind the inlet tip under the fan. Interaction of this inflow distortion was the dominant source of noise at 1, 2, and 3 times blade passing frequency (BPF) at 60, 70, and 80 percent of design speed. At 90 percent speed, noise at BPF was dominated by the steady rotor field. A broadband spectrum peak centered at about 2.2 times BPF was identified as rotor/stator interaction stemming from a high frequency rotor exit flow component. The remaining broadband energy from 0.3 to 3.5 times BPF was attributed to the better known type of rotor/stator interaction associated with rotor wake turbulence. Author

**A77-51069\*** Forward flight effects on EBF noise. M. R. Fink (United Technologies Research Center, East Hartford, Conn.). American Institute of Aeronautics and Astronautics, Aerodynamics Conference, 4th, Atlanta, Ga., Oct. 3-5, 1977, Paper 77-1314, 12 p. 16 refs. Contract No. NAS3-17863.

Forward flight effects on local mean velocity and turbulence velocity profiles, surface pressure spectra, and far field acoustic pressure spectra were measured for a simple externally blown flap (EBF). Both upper-surface-blowing and under-the-wing configurations were tested. Ratio of acoustic wind tunnel velocity to nozzle exhaust velocity was varied from 0 to 3/8 in steps of 1/8. A method was determined for predicting forward flight effects on surface-radiated noise. This noise is decreased in amplitude and shifted to higher frequency relative to data obtained at zero flight speed. Predictions are validated by comparisons with published NASA, Boeing, and Lockheed data. (Author)

## 03 AIR TRANSPORTATION AND SAFETY

Includes passenger and cargo air transport operations, and aircraft accidents.

For related information see also 16 Space Transportation and 85 Urban Technology and Transportation.

**N77-18088\*** National Aeronautics and Space Administration, Lewis Research Center, Cleveland, Ohio

### STATUS OF NASA AIRCRAFT ENGINE EMISSION REDUCTION AND UPPER ATMOSPHERE MEASUREMENT PROGRAMS

Richard A. Rudy and Erwin A. Lezberg. *In its Aircraft Safety and Operating Problems* 1976 p 319-336 refs (For primary document see N77-18081 09-03)

Avail NTIS HC A99/MF A01 CSCL 21E

Advanced emission reduction techniques for five existing aircraft gas turbine engines are evaluated. Progress made toward meeting the 1979 EPA standards in rig tests of combustors for the five engines is reported. Results of fundamental combustion studies suggest the possibility of a new generation of jet engine combustor technology that would reduce oxides-of-nitrogen (NOx) emissions far below levels currently demonstrated in the engine-related programs. The Global Air Sampling Program (GAS) is now in full operation and is providing data on constituent measurements of ozone and other minor upper atmosphere species related to aircraft emissions. Author

**N77-18103\*** National Aeronautics and Space Administration, Lewis Research Center, Cleveland, Ohio

### CONCEPTS FOR IMPROVING TURBINE DISK INTEGRITY

Albert Kaufman. *In its Aircraft Safety and Operating Problems* 1976 p 423-442 refs (For primary document see N77-18081 09-03)

Avail NTIS HC A99/MF A01 CSCL 21E

Advanced disk structural concepts are used to improve the cyclic lives and reliability of turbine disks. Analytical studies were conducted to evaluate bore-entry disks as potential replacements for the existing first stage turbine disks in the CF6-50 and JT8D-17 engines. Results of low-cycle fatigue, burst, fracture mechanics, and fragment energy analyses are summarized for the advanced disk designs and the existing disk designs with both conventional and advanced disk materials. Other disk concepts such as composite, laminated link, multibore, multidisk, and spline disks were also evaluated for the CF6-50 engine. Author

**N77-18104\*** National Aeronautics and Space Administration, Lewis Research Center, Cleveland, Ohio

### AIRCRAFT ENGINE SUMP-FIRE STUDIES

William R. Loomis. *In its Aircraft Safety and Operating Problems* 1976 p 443-456 refs (For primary document see N77-18081 09-03)

Avail NTIS HC A99/MF A01 CSCL 21E

Results of ongoing experimental studies are reported in which a 125-millimeter-diameter-advanced-bearing test rig simulating an engine sump is being used to find the critical range of conditions for fires to occur. Design, material, and operating concepts and techniques are being studied with the objective of minimizing the problem. It has been found that the vapor temperature near a spark ignitor is most important in determining ignition potential. At temperatures producing oil vapor pressures below or much above the calculated flammability limits, fires have not been ignited. But fires have been routinely started within the theoretical flammability range. This indicates that generalizing the sump-fire problem may make it amenable to analysis with the potential for realistic solutions. Author

**N77-18105\*** National Aeronautics and Space Administration, Lewis Research Center, Cleveland, Ohio

### ALTERNATIVE AIRCRAFT FUELS TECHNOLOGY

Jack Grobman. *In its Aircraft Safety and Operating Problems* 1976 p 457-468 refs (For primary document see N77-18081 09-03)

Avail NTIS HC A99/MF A01 CSCL 21D

NASA is studying the characteristics of future aircraft fuels produced from either petroleum or nonpetroleum sources such as oil shale or coal. These future hydrocarbon based fuels may have chemical and physical properties that are different from present aviation turbine fuels. This research is aimed at determining what those characteristics may be, how present aircraft and engine components and materials would be affected by fuel specification changes, and what changes in both aircraft and engine design would be required to utilize these future fuels without sacrificing performance, reliability, or safety. This fuels technology program was organized to include both in-house and contract research on the synthesis and characterization of fuels, component evaluations of combustors, turbines, and fuel systems, and, eventually full-scale engine demonstrations. A review of the various elements of the program and significant results obtained so far are presented. Author

**N77-18106\*** National Aeronautics and Space Administration, Lewis Research Center, Cleveland, Ohio

### GAS-PATH SEAL TECHNOLOGY

John Zuk. *In its Aircraft Safety and Operating Problems* 1976 p 469-480 refs (For primary document see N77-18081 09-03)

Avail NTIS HC A99/MF A01 CSCL 11A

Improved gas-path seals are needed for better fuel economy, longer performance retention, and lower maintenance, particularly in advanced, high performance gas turbine engines. Problems encountered in gas-path sealing are described, as well as new blade-tip sealing approaches for high-pressure compressors and turbines. These include a lubricant coating for conventional, porous-metal rub-strip materials used in compressors. An improved hot-press metal alloy shows promise to increase the operating surface temperatures of high pressure turbine blade-tip seals to 1450 K (2150 F). Three ceramic seal materials are also described that have the potential to allow much higher gas-path surface operating temperatures than are possible with metal systems. Author

**N77-18108\*** National Aeronautics and Space Administration, Lewis Research Center, Cleveland, Ohio

### DEVELOPMENTS IN AIRCRAFT JET NOISE TECHNOLOGY

Orlando A. Gutierrez and James R. Stone. *In its Aircraft Safety and Operating Problems* 1976 p 497-512 refs (For primary document see N77-18081 09-03)

Avail NTIS HC A99/MF A01 CSCL 20A

Significant developments in two areas of jet noise technology are described: the development of jet noise technology relative to coannular nozzles of all types, and a recent approach to the analysis of flight effects that appears to allow simulated flight effects results to be transformed to actual flight conditions with a high degree of confidence. The coannular nozzle section presents results applicable to high-bypass-ratio turbofan engines, as well as current work on inverted-profile coannular nozzles applicable to low-bypass-ratio turbofan engines suitable for use in future supersonic cruise aircraft. Author

**N77-33114# Douglas Aircraft Co. Inc., Long Beach, Calif  
WIND TUNNEL AND ANALYTICAL INVESTIGATION OF  
OVER-THE-WING /PROPULSION/AIR FRAME INTERFER-  
ENCES FOR A SHORT-HAUL AIRCRAFT AT MACH  
NUMBERS FROM 0.6 TO 0.78 Final Report**

O. D. Wells, M. L. Lopez, H. R. Waite, P. A. Henne, and A. E.  
Sewell Washington NASA Sep. 1977 244 p refs  
(Contract NAS3-16284)  
(NASA-CR-2905; MDC-J7601) Avail: NTIS HC A11/MF A01  
CSCL 01A

Results of analytical calculations and wind tunnel tests at cruise speeds of a representative four engine short haul aircraft employing upper surface blowing (USB) with a supercritical wing are discussed. Wind tunnel tests covered a range of Mach number M from 0.6 to 0.78. Tests explored the use of three USB nozzle configurations. Results are shown for the isolated wing body and for each of the three nozzle types installed. Experimental results indicate that a low angle nacelle and streamline contour nacelle yielded the same interference drag at the design mach number. A high angle powered lift nacelle had higher interference drag primarily because of nacelle boattail low pressures and flow separation. Results of varying the spacing between the nacelles and the use of trailing edge flap deflections, wing upper surface contouring, and a convergent-divergent nozzle to reduce potential adverse jet effects were also discussed. Analytical comparisons with experimental data, made for selected cases, indicate favorable agreement.

Author

## 05 AIRCRAFT DESIGN, TESTING AND PERFORMANCE

Includes aircraft simulation technology.  
For related information see also 18 Spacecraft Design, Testing and Performance and 39 Structural Mechanics.

**N77-12089\*** National Aeronautics and Space Administration Lewis Research Center, Cleveland, Ohio.

### SUMMARY OF NASA AERODYNAMIC AND HEAT TRANSFER STUDIES IN TURBINE VANES AND BLADES

Thomas P. Moffitt, Francis S. Stepka, and Harold E. Rohlik 1976 52 p. refs. Presented at Aerospace Eng. and Mfg. Meeting, San Diego, Calif., 29 Nov. - 2 Dec. 1976, sponsored by SAE (NASA-TM-X-73518) Avail: NTIS HC A04/MF A01 CSCL 21K

Aerodynamic effects of trailing edge geometry, hole size, angle, spacing, and shape were studied in two- and three-dimensional cascades and in a warm turbine test series. Heat transfer studies were carried out in various two- and three-dimensional test facilities in order to provide corresponding heat transfer data. Results are shown in terms of cooling effectiveness and aerodynamic efficiency for various coolant fractions, coolant-primary temperature ratios, and cooling configurations.

Author

**N77-18020\*** National Aeronautics and Space Administration Lewis Research Center, Cleveland, Ohio.

### AEROACOUSTIC STUDIES OF COANNULAR NOZZLES SUITABLE FOR SUPERSONIC CRUISE AIRCRAFT APPLICATIONS

Orlando A. Gutierrez In its Proc. of the SCAR Conf., Pt. 2, 1976 20 p. refs. (For primary document see N77 18019 09-01) Avail: NTIS HC A23/MF A01 CSCL 01C

**N77-27107\*** National Aeronautics and Space Administration Lewis Research Center, Cleveland, Ohio.

### USE OF EXPERIMENTAL SEPARATION LIMITS IN THE THEORETICAL DESIGN OF V/STOL INLETS

Michael A. Boles (Indiana Inst. of Technology) and Norbert O. Stockman Jul 1977 24 p. refs. Presented at the 13th Propulsion Conf., Orlando, Fla., 11-13 Jul. 1977; sponsored by AIAA and SAE

(NASA-TM-73709) Avail: NTIS HC A02/MF A01 CSCL 01C

Experimental data from several model inlets are used to generate two parameters which are related to the limit of operation for inlet flow separation. One parameter, called the diffusion ratio, is the ratio of the peak velocity on the inlet surface to the velocity at the diffuser exit and is related to the boundary layer separation at low throat Mach numbers. The other parameter, the peak Mach number on the inlet surface, is related to the separation at high throat Mach numbers. These parameters are easily calculated from potential flow solutions and thus can be used as a design tool in screening proposed inlet geometries. An illustrative example of an application to an inlet design study for a tilt nacelle VTOL airplane is presented. The value of contraction ratio required to meet the operating requirements yet allow the inlet to remain free of separation as indicated by the two separation parameters is shown.

Author

**A77-18982\*** \* Flap noise and aerodynamic results for model OCSEE over-the-wing configurations. W. Olson, R. Burns, and D. Groesbeck (NASA, Lewis Research Center, Cleveland, Ohio). American Institute of Aeronautics and Astronautics, Aerospace Sciences Meeting, 15th, Los Angeles, Calif., Jan. 24-26, 1977, Paper 77-23, 26 p. 15 refs.

Noise spectra in three dimensions and aerodynamic data were measured for a model of the NASA OCSEE (Quiet Clean Short Haul Experimental Engine) over-the-wing configuration. The effects of flap length, nozzle exhaust velocity, and nozzle geometry were

determined using a single nozzle and wing-flap segment. Related tests indicated that the scaled-up model data would be representative of full scale flap noise with the OCSEE engine. The scaled-up OCSEE model data imply that the noise goal will be very nearly attained.

(Author)

**A77-34982\*** \* Analysis of control concepts for gas and shaft-coupled V/STOL aircraft lift fan systems. J. F. Sellers, C. E. Hart, and J. R. Mihalevich (NASA, Lewis Research Center, Cleveland, Ohio). In: V/STOL Conference, Palo Alto, Calif., June 6-8, 1977, Technical Papers. (A77 34926 15-05) New York, American Institute of Aeronautics and Astronautics, Inc., 1977, p. 282-292, 16 refs. (AIAA 77-611)

V/STOL aircraft rely on their propulsion systems to provide lift and attitude control moments during hover and low-speed flight. For lift-fan powered V/STOL aircraft, two unconventional propulsion system types have been proposed. The first type uses fans connected by hot gas ducting, and the second type uses fans connected by cross shafting. This paper presents results of an analytical study which identifies the basic steady-state and dynamic characteristics for each type of system. For the gas coupled system, the control concepts analyzed were variable area fan turbines and throttling valves in the ducting. For the shaft coupled system, the control concepts analyzed were variable pitch fans and variable fan inlet guide vanes. All of these concepts are shown to be capable of meeting V/STOL aircraft control moment and transient response requirements when appropriate propulsion controls are used. Each type of system has unique problem areas which require an integrated approach to aircraft/propulsion control design.

(Author)

**A77-38021\*** Large quantity, high speed pressure data acquisition. E. Armentrout (NASA, Lewis Research Center, Cleveland, Ohio), R. Keller (Boeing Commercial Airplane Co., Seattle, Wash.), and J. C. Kicks (Kuntz Semiconductor Products, Inc., Ridgefield, N.J.). In: The many disciplines of flight test, Proceedings of the Seventh Annual Symposium, Eastsound, Orcas Island, Wash., August 4-6, 1976 (A77 38003 17-05) Lancaster, Calif., Society of Flight Test Engineers, 1976, p. 201 to 2015.

Approaches used for conducting in-flight pressure surveys for aircraft are examined, taking into account difficulties related to a use of scanwheels which are employed only in cases in which there is not sufficient space for the mounting of individual transducers. In connection with attempts to eliminate these difficulties a new pressure survey module was manufactured. The dimensions of the new module make it possible to mount it in places in which the old scanwheel module could be mounted. One of the difficulties related to the use of the old scanwheel module has been the risk of data loss in flight in connection with the migration of foreign matter within the tubing. In the new module an electrical sampling method is employed to eliminate this risk. Attention is also given to an engine ground test and preflight system and the development of a calibration module.

G R

**A77-44324\*** \* Advanced turboprop technology development. J. F. Dugan (NASA, Lewis Research Center, Cleveland, Ohio), D. P. Benz, and L. J. Williams (NASA, Ames Research Center, Moffett Field, Calif.). American Institute of Aeronautics and Astronautics, Aircraft Systems and Technology Meeting, Seattle, Wash., Aug. 22-24, 1977, Paper 77-1223, 16 p. 17 refs.

In order for new short-medium range transports to offer significantly lower operating costs than potential derivatives of current designs using advanced technology, the efficiency improvements of high speed turboprop propulsion systems may be required. Recent studies indicate that the fuel savings of advanced turboprop aircraft appears to be 10 to 20 percent relative to equivalent technology turbofan aircraft. These fuel savings are certainly large enough to warrant further research to establish the viability of turboprop transport aircraft. The studies have identified the technology requirements in propeller design for high efficiency and low noise, fuselage noise attenuation, propeller and gear box mainte-

nance, and engine-airframe integration. This paper presents a review of present research in each of these areas and describes the future plans for continued development of the technology for advanced turboprop transport aircraft. (Author)

**A77-51072 \* #** Interim noise correlation for some OTW configurations using external jet-flow deflectors. U. von Glahn and D. Groesbeck (NASA, Lewis Research Center, Cleveland, Ohio). *American Institute of Aeronautics and Astronautics, Aerodynamics Conference, 4th, Atlanta, Ga., Oct. 3-5, 1977, Paper 77-1317*. 27 p. 5 refs.

Jet/flap interaction acoustic data obtained statically from a model-scale study of STOL-OTW configurations with a conical nozzle mounted above the wing and using various external deflectors to provide jet-flow attachment are correlated. The acoustic data are correlated in terms that consider the jet/flap interaction noise contributions associated primarily with fluctuating lift, trailing edge, and configuration wake noise sources. Variables considered include deflector geometry, flap setting and wing size. Finally, the configuration overall noise levels are related to static lift and thrust measurements in order to provide insight into possible acoustic/aerodynamic performance trade-off benefits. (Author)

**A77-51073 \* #** Over-the-wing model thrust reverser noise tests. J. Goodykoontz and O. Gutierrez (NASA, Lewis Research Center, V/STOL and Noise Div., Cleveland, Ohio). *American Institute of Aeronautics and Astronautics, Aerodynamics Conference, 4th, Atlanta, Ga., Oct. 3-5, 1977, Paper 77-1318*. 20 p. 10 refs.

Experimental results are presented for static acoustic tests of a 1/12 scale model over-the-wing target type thrust reverser. The model configuration simulates a design that is applicable to the over-the-wing short-haul advanced technology engine. Aerodynamic screening tests of a variety of reverser designs identified configurations that satisfied a reverse thrust requirement of 35 percent of forward thrust at a nozzle pressure ratio of 1.29. The variations in the reverser configuration included, blocker door angle, blocker door lip angle and shape, and side skirt shape. Acoustic data are presented and compared for the various configurations. The model data scaled to a single full size engine show that peak free field perceived noise levels at a 152.4 meter sideline distance range from 98 to 104 PNdB. (Author)

**N77-12041\*#** General Electric Co., Cincinnati, Ohio.  
**ANALYSIS OF PRESSURE DISTORTION TESTING Final Report**

K. E. Koch and R. L. Reas Washington NASA Dec. 1976  
103 p refs

(Contract NAS3-19522)  
(NASA-CR-2766 Rept-76AEG272)  
HC A08/MF A01 CSCL 200

Avail: NTIS

The development of a distortion methodology, method D, was documented, and its application to steady state and unsteady data was demonstrated. Three methodologies based upon DIDENT, a NASA-LaRC distortion methodology based upon the parallel compressor model, were investigated by applying them to a set of steady state data. The best formulation was then applied to an independent data set. The good correlation achieved with this data set showed that method E, one of the above methodologies, is a viable concept. Unsteady data were analyzed by using the method E methodology. This analysis pointed out that the method E sensitivities are functions of pressure defect level as well as corrected speed and pattern. (Author)

**N77-10022\*#** Pratt and Whitney Aircraft, East Hartford, Conn.  
Commercial Products Div.  
**CIRCUMFERENTIAL DISTORTION MODELING OF THE TF30-P-3 COMPRESSION SYSTEM**  
R. S. Mazzawy and G. A. Banks Jan. 1977 91 p refs  
(Contract NAS3-18535)  
(NASA-CR-135124; PWA-5448)  
HC A05/MF A01 CSCL 21E

Avail: NTIS

Circumferential inlet pressure and temperature distortion testing of the TF30 P-3 turbofan engine was conducted. The compressor system at the test conditions run was modeled according to a multiple segment parallel compressor model. Aspects of engine operation and distortion configuration modeled include the effects of compressor bleeds, relative pressure-temperature distortion alignment and circumferential distortion extent. Model predictions for limiting distortion amplitudes and flow distributions within the compression system were compared with test results in order to evaluate predicted trends. Relatively good agreement was obtained. The model also identified the low pressure compressor as the stall-initiating component, which was in agreement with the data. (Author)

## 06 AIRCRAFT INSTRUMENTATION

Includes cockpit and cabin display devices; and flight instruments.

For related information see also 19 Spacecraft Instrumentation and 35 Instrumentation and Photography.

**N77-22105\*** National Aeronautics and Space Administration, Lewis Research Center, Cleveland, Ohio.

### ANALYSIS OF DYNAMIC INLET DISTORTION APPLIED TO A PARALLEL COMPRESSOR MODEL

Leon M. Wenzel and Ronald J. Blaha Washington May 1977  
24 p refs  
(NASA-TM-X-3522, E-8979) Avail: NTIS HC A02/MF A01  
CSCL 21E

An investigation of surge was conducted by using a parallel compressor model of the J85-13 compressor implement on an analog computer. Surges were initiated by various types of dynamic disturbances in inlet pressure. The compressor model was less sensitive to disturbances of short duration, high frequency, and long duration where the compressor discharge pressure could react. Adding steady distortion to dynamic disturbances reduced the amount of dynamic disturbance required to effect surge. Steady and unsteady distortions combined linearly to reduce surge margin.

Author

**N77-22106\*** National Aeronautics and Space Administration, Lewis Research Center, Cleveland, Ohio.

### DYNAMICS OF HIGH-BYPASS-ENGINE THRUST REVERSAL USING A VARIABLE-PITCH FAN

John W. Schaefer, David R. Sagerser, and Edward G. Stokolich Washington May 1977 35 p refs  
(NASA-TM-X-3524, E-9026) Avail: NTIS HC A03/MF A01  
CSCL 21E

The test program demonstrated that successful and rapid forward-to reverse-thrust transients can be performed without any significant engine operational limitations for fan blade pitch changes through either feather pitch or flat pitch. For through-feather-pitch operation with a flight inlet, fan stall problems were encountered, and a fan blade overshoot technique was used to establish reverse thrust.

Author

**N77-22107\*** National Aeronautics and Space Administration, Lewis Research Center, Cleveland, Ohio.

### PRELIMINARY STUDIES OF AUTOIGNITION AND FLASHBACK IN A PREMIXING-PREVAPORIZING FLAME TUBE USING JET-A FUEL AT LEAN EQUIVALENCE RATIOS

Cecil J. Marek, Leonidas C. Papathakos, and Peter W. Verbulecz Washington May 1977 14 p refs  
(NASA-TM-X-3526, E 9039) Avail: NTIS HC A02/MF A01  
CSCL 21E

Lean equivalence ratios from 0.3 to 0.7 were observed. Combustor inlet air pressures were varied from 0.54 to 2.5 MPa, combustor inlet air temperatures from 550 to 700 K, and reference velocities from 8 to 35 meters per second. Autoignition delay times ranged from 15 to 100 milliseconds and varied inversely with pressure. The Arrhenius activation energy was 41,840 joules per mole. Temperature rise data were obtained in a long premixing-prevaporizing tube at a pressure of 0.56 MPa. Preflame temperature rise data were a function of equivalence ratio, inlet air temperature, and tube residence time. Significant temperature rise occurred above temperatures of 760 K, with autoignition occurring at 775 K for equivalence ratios greater than 0.47. The reactions were similar to cool-flame phenomena. Flashback velocities were measured at temperatures of 610 and 700 K, pressure of 0.56 MPa, and equivalence ratios from 0.6 to 1. Flashback velocities varied from 30 to 65 meters per second.

Author



## 07 AIRCRAFT PROPULSION AND POWER

Includes prime propulsion systems and systems components, e.g. gas turbine engines and compressors; and on-board auxiliary power plants for aircraft.

For related information see also 20 Spacecraft Propulsion and Power, 28 Propellants and Fuels, and 44 Energy Production and Conversion.

**N77-10057\*** National Aeronautics and Space Administration, Lewis Research Center, Cleveland, Ohio.

### TOWARD MORE ENVIRONMENTALLY RESISTANT GAS TURBINES: PROGRESS IN NASA-LEWIS PROGRAMS

Carl E. Lowell, Salvatore J. Grisaffe, and Stanley R. Levine 1976 24 p refs Presented at 3d Conf. on Gas Turbine Mater. in a Marine Environ., Bath, Engl., 20-23 Sep 1976 (NASA-TM-X-73499) Avail: NTIS HC A02/MF A01 CSCL 21E

A wide range of programs are being conducted for improving the environmental resistance to oxidation and hot corrosion of gas turbine and power system materials. They range from fundamental efforts to delineate attack mechanisms, allow attack modeling and permit life prediction, to more applied efforts to develop potentially more resistant alloys and coatings. Oxidation life prediction efforts have resulted in a computer program which provides an initial method for predicting long time metal loss using short time oxidation data by means of a parabolic attack model. Efforts in alloy development have centered on oxide-dispersion strengthened alloys based on the Ni-Cr-Al system. Compositions have been identified which are compromises between oxidation and thermal fatigue resistance. Fundamental studies of hot corrosion mechanisms include thermodynamic studies of sodium sulfate formation during turbine combustion. Information concerning species formed during the vaporization of  $\text{Na}_2\text{SO}_4$  has been developed using high temperature mass spectrometry.

Author

**N77-10058\*** National Aeronautics and Space Administration, Lewis Research Center, Cleveland, Ohio.

### EMISSIONS OF AN AVCO LYCOMING O-320-DIAD AIR COOLED LIGHT AIRCRAFT ENGINE AS A FUNCTION OF FUEL-AIR RATIO, TIMING, AND AIR TEMPERATURE AND HUMIDITY

Phillip R. Meng, Michael Skorobatchky, Donald V. Cosgrove, and Erwin E. Kampke Aug. 1976 208 p refs (NASA-TM-X-73500) Avail: NTIS HC A10/MF A01 CSCL 21G

A carburetor aircraft engine was operated over a range of test conditions to establish the exhaust levels over the EPA seven-mode emissions cycle. Baseline (full rich production limit) exhaust emissions at an induction air temperature of 59 F and near zero relative humidity were 90 percent of the EPA standard for HC, 35 percent for  $\text{NO}_x$ , and 181 percent for CO. Changes in ignition timing around the standard 25 deg BTDC from 30 deg BTDC to 20 deg BTDC had little effect on the exhaust emissions. Retarding the timing to 15 deg BTDC increased both the HC and CO emissions and decreased  $\text{NO}_x$  emissions. HC and CO emissions decreased as the carburetor was leaned out, while  $\text{NO}_x$  emissions increased. The EPA emission standards were marginally achieved at two leanout conditions. Variations in the quantity of cooling air flow over the engine had no effect on exhaust emissions. Temperature-humidity effects at the higher values of air temperature and relative humidity tested indicated that the HC and CO emissions increased significantly, while the  $\text{NO}_x$  emissions decreased.

Author

**N77-10059\*** National Aeronautics and Space Administration, Lewis Research Center, Cleveland, Ohio.

### SUPERSONIC VARIABLE-CYCLE ENGINES

E. A. Willis and A. D. Welliver (Boeing Aerospace Co., Seattle, Wash.) 1976 11 p refs Presented at the 12th Propulsion Conf., Palo Alto, Calif., 26-29 Jul. 1976; cosponsored by AIAA and SAE (NASA-TM-X-73524) Avail: NTIS HC A02/MF A01 CSCL 21E

The evolution and current status of selected recent variable cycle engine (VCE) studies are reviewed, and how the results were influenced by airplane requirements is described. Promising VCE concepts are described, their designs are simplified and the potential benefits in terms of aircraft performance are identified. This includes range, noise, emissions, and the time and effort it may require to ensure technical readiness of sufficient depth to satisfy reasonable economic, performance, and environmental constraints. A brief overview of closely related, ongoing technology programs in acoustics and exhaust emissions is also presented. Realistic technology advancements in critical areas combined with well matched aircraft and selected VCE concepts can lead to significantly improved economic and environmental performance relative to first generation SST predictions.

Author

**N77-10062\*** National Aeronautics and Space Administration, Lewis Research Center, Cleveland, Ohio.

### ADVANCED COMBUSTION TECHNIQUES FOR CONTROLLING NO SUB X EMISSIONS OF HIGH ALTITUDE CRUISE AIRCRAFT

R. A. Rudey and G. M. Rock 1976 21 p refs Presented at 27th Intern. Astronaut Congr., Anaheim, Calif., 10-16 Oct. 1976; sponsored by AIAA (NASA-TM-X-73473; E-8856) Avail: NTIS HC A02/MF A01 CSCL 21E

An array of experiments designed to explore the potential of advanced combustion techniques for controlling the emissions of aircraft into the upper atmosphere was discussed. Of particular concern are the oxides of nitrogen ( $\text{NO}_x$ ) emissions into the stratosphere. The experiments utilize a wide variety of approaches varying from advanced combustor concepts to fundamental flame tube experiments. Results are presented which indicate that substantial reductions in cruise  $\text{NO}_x$  emissions should be achievable in future aircraft engines. A major NASA program is described which focuses the many fundamental experiments into a planned evolution and demonstration of the prevaporized-premixed combustion technique in a full-scale engine.

Author

**N77-10063\*** National Aeronautics and Space Administration, Lewis Research Center, Cleveland, Ohio.

### THE IMPACT OF EMISSIONS STANDARDS ON THE DESIGN OF AIRCRAFT GAS TURBINE ENGINE COMBUSTORS

Richard A. Rudey 1976 19 p refs Presented at the Aerospace Conf., San Diego, Calif., 29 Nov - 2 Dec. 1976; sponsored by SAE (NASA-TM-X-73490) Avail: NTIS HC A02/MF A01 CSCL 21E

Effective emission control techniques have been identified and a wide spectrum of potential applications for these techniques to existing and advanced engines are being considered. Results from advanced combustor concept evaluations and from fundamental experiments are presented and discussed and comparisons are made with existing EPA emission standards and recommended levels for high altitude cruise. The impact that the advanced low emission concepts may impose on future aircraft engine combustor designs and related engine components is discussed.

Author

**N77-10086\*** National Aeronautics and Space Administration  
Lewis Research Center, Cleveland, Ohio.

**EFFECT OF AIR TEMPERATURE AND RELATIVE HUMIDITY AT VARIOUS FUEL-AIR RATIOS ON EXHAUST EMISSIONS ON A PER-MODE BASIS OF AN AVCO LYCOMING O-320 DIAD LIGHT AIRCRAFT ENGINE. VOLUME 2: INDIVIDUAL DATA POINTS**

Michael Skorobatchkyi, Donald V. Cosgrove, Philip R. Meng, and Edward R. Kempko Sep 1976 850 p  
(NASA-TM-X-73507, E-8916-Vol-2) Avail: NTIS HC A99/MF A01 CSCL 21E

A carbureted four cylinder air cooled O-320 Lycoming aircraft engine was tested to establish the effects of air temperature and humidity at various fuel-air ratios on the exhaust emissions on a per-mode basis. The test conditions included carburetor lean-out at air temperatures of 50, 59, 80, and 100 F at relative humidities of 0, 30, 60, and 80 percent. Temperature-humidity effects at the higher values of air temperature and relative humidity tested indicated that the HC and CO emissions increased significantly, while the NOx emissions decreased. Even at a fixed fuel-air ratio, the HC emissions increase and the NOx emissions decrease at the higher values of air temperature and humidity. Volume II contains the data taken at each of the individual test points. Author

**N77-11050\*** National Aeronautics and Space Administration  
Lewis Research Center, Cleveland, Ohio

**SIMULATION OF FLIGHT-TYPE ENGINE FAN NOISE IN THE NASA-LEWIS 9X15 ANECHOIC WIND TUNNEL**

M. F. Heidmann and D. A. Dietrich Nov 1976 24 p refs  
Presented at the 92d Meeting of the Acoust. Soc. of Am. San Diego, Calif., 16-19 Nov. 1976  
(NASA-TM-X-73540 E 8972) Avail: NTIS HC A02/MF A01 CSCL 20A

Flight type noise as contrasted to the usual ground static test noise exhibits substantial reductions in the time unsteadiness of tone noise, and in the mean level of tones calculated to be nonpropagating or cut off. A model fan designed with cutoff of the fundamental tone was acoustically tested in the anechoic wind tunnel under both static and tunnel flow conditions. The properties that characterize flight type noise were progressively simulated with increasing tunnel flow. The distinctly lobed directivity pattern of propagating rotor/stator interaction modes was also observed. Excess noise attributed to the ingestion of the flow disturbances that prevail near most static test facilities is substantially reduced with tunnel flow. Author

**N77-11051\*** National Aeronautics and Space Administration  
Lewis Research Center, Cleveland, Ohio

**EFFECTS OF FORWARD VELOCITY ON NOISE FOR A J85 TURBOJET ENGINE WITH MULTITUBE SUPPRESSOR FROM WIND TUNNEL AND FLIGHT TESTS**

James R. Stone, Jeffrey H. Miles, and Noel B. Sargent Nov 1976 30 p refs  
Presented at the 92d Meeting of the Acoustical Soc. of Am., San Diego, Calif., 16-19 Nov. 1976  
(NASA-TM-X-73542, E-8974) Avail: NTIS HC A03/MF A01 CSCL 20A

Flight and wind tunnel noise tests were conducted using a J85 turbojet engine as a part of comprehensive programs to obtain an understanding of forward velocity effects on jet exhaust noise. Nozzle configurations of primary interest were a 104-tube suppressor with and without an acoustically-treated shroud. The installed configuration of the engine was as similar as possible in the flight and wind tunnel tests. Exact simultaneous matching of engine speed, exhaust velocity, and exhaust temperature was not possible, and the wind tunnel maximum Mach number was approximately 0.27 while the flight Mach number was approximately 0.37. The nominal jet velocity range was 450 to 640 m/sec. For both experiments, background noise limited the jet velocity range for which significant data could be obtained. In the present tests the observed directivity and forward velocity effects for the suppressor are more similar to predicted trends for internally-generated noise than unsuppressed jet noise. Author

**N77-11052\*** National Aeronautics and Space Administration  
Lewis Research Center, Cleveland, Ohio

**MACROSCOPIC STUDY OF TIME UNSTEADY NOISE OF AN AIRCRAFT ENGINE DURING STATIC TESTS**

B. J. Clark, M. F. Heidmann, and W. J. Kraim Nov 1976 14 p refs  
Presented at the 92d Meeting of the Acoustical Soc. of Am. San Diego, Calif., 16-19 Nov. 1976  
(NASA-TM-X-73556, E-8995) Avail: NTIS HC A02/MF A01 CSCL 20A

Static tests of aircraft engines can exhibit greater than 10 db random unsteadiness of tone noise levels because flow disturbances that prevail near test site facilities are ingested. Presumably such changes are related to installation and test site features. Some properties of unsteady noise observed during tests of a Lycoming YF-102 turbofan engine are presented. Time and spatial variations in tone noise obtained from closely spaced far field and inlet duct microphones are displayed. Long to extremely short intermittent tone bursts are observed. Unsteadiness of the tone, its harmonics, and the broadband noise show little similarity in the far field. Identity of tone bursts is retained over a directivity angle of less than 10 deg. In the inlet duct, tone bursts appear to propagate axially but exhibit little circumferential similarity. They show only slight relationship to tone bursts observed in the far field. The results imply an intermittent generation of random mixtures of propagating duct modes. Author

**N77-11053\*** National Aeronautics and Space Administration  
Lewis Research Center, Cleveland, Ohio

**CORE NOISE SOURCE DIAGNOSTICS ON A TURBOFAN ENGINE USING CORRELATION AND COHERENCE TECHNIQUES**

Allen Karchmer and Meyer Roshotko Nov 1976 27 p refs  
Presented at the ninety-second Meeting of the Acoust. Soc. of Am. San Diego, Calif., 16-19 Nov. 1976  
(NASA-TM-X-73535, E-8961) Avail: NTIS HC A03/MF A01 CSCL 21E

Fluctuating pressure measurements at several locations within the core of a turbofan engine were made simultaneously with far field acoustic measurements. Correlation and coherence techniques were used to determine the relative amplitude and phase relationships between core pressures at these various locations and between the core pressures and far field acoustic pressure. The combustor is a low frequency source region for acoustic propagation through the core nozzle and out to the far field. The relation between source pressure and the resulting sound pressure involves a 180 degree phase shift and an amplitude transfer function which varies approximately as frequency squared. This is consistent with a simplified model using fluctuating entropy as a source term. Author

**N77-11056\*** National Aeronautics and Space Administration  
Lewis Research Center, Cleveland, Ohio

**PERFORMANCE AND EMISSION CHARACTERISTICS OF SWIRL-CAN COMBUSTORS TO NEAR STOICHIOMETRIC FUEL-AIR RATIO**

Larry A. Diehl and Arthur M. Trout Washington Nov 1976 41 p refs  
(NASA TN-D-8342, E-8718) Avail: NTIS HC A03/MF A01 CSCL 21E

Emissions and performance characteristics were determined for two full annular swirl-can combustors operated to near stoichiometric fuel-air ratio. Test condition variations were as follows: combustor inlet-air temperatures, 589, 762, 839, and 894 K; reference velocities, 24 to 37 meters per second; inlet pressure, 62 newtons per square centimeter; and fuel-air ratios, 0.015 to 0.065. The combustor average exit temperature and combustor efficiency were calculated from the combustor exhaust gas composition. For fuel-air ratios greater than 0.04, the combustion efficiency decreased with increasing fuel-air ratios in a near-linear manner. Increasing the combustor inlet air temperature tended to offset this decrease. Maximum oxides of nitrogen emission indices occurred at intermediate fuel-air ratios and were dependent on combustor design. Carbon monoxide levels were extremely high and were the primary cause of poor combustion efficiency at the higher fuel-air ratios. Unburned hydrocarbons were low for all test conditions. For high fuel-air

ratios SAE smoke numbers greater than 25 were produced, except at the highest inlet air temperatures Author

**N77-11057\*** National Aeronautics and Space Administration, Lewis Research Center, Cleveland, Ohio.  
**METHOD OF DISCRETE MODELING AND ITS APPLICATION TO ESTIMATION OF TF30 ENGINE VARIABLES**  
Dale J. Arpaia and William M. Bruton, Oct. 1976 40 p refs (NASA-TM-X-3443, E-8560) Avail NTIS HC A03/MF A01 CSDL 21E

A method of discrete modeling is presented that effectively isolates steady state mode accuracy from dynamic model accuracy. The steady state model may be generated from the engine design equations with any desired degree of accuracy. The dynamic model is generated by applying a step disturbance of a manipulated variable to an open loop engine simulation. The sampled response of the variable is combined with the steady state model's response to form a set of weighting factors. These weighting factors are then used to weight past values of the manipulated variable, thus forming the dynamic model. The method is used to estimate various TF30-P-3 engine variables. A dynamic trim function is developed to compensate for the dynamic nonlinearities of the variables as well as for inaccuracies in dynamic definition. The trim function is shown to be related to the square root of the sum of the squares of the weighting factors obtained at various engine operating conditions. Finally, the estimation of variables without dynamic modeling is discussed. Author

**N77-13084\*** National Aeronautics and Space Administration, Lewis Research Center, Cleveland, Ohio.  
**COST/BENEFIT ASSESSMENT OF THE APPLICATION OF COMPOSITE MATERIALS TO SUBSONIC COMMERCIAL TRANSPORT ENGINES**  
J. R. Faddoul and R. A. Signorelli, Nov. 1976 33 p refs (NASA-TM-X-73557, E-8996) Avail NTIS HC A03/MF A01 CSDL 21E

Results from a number of studies concerned with the cost and benefits of applying advanced composite materials to commercial turbofan engines are summarized. For each application area the optimistic and pessimistic benefit projections were averaged to arrive at a projected yearly percentage fuel savings for a commercial fleet of advanced technology transport aircraft. Engine components included in the summary are the fan section which includes fan blades, fan frame/case, and the blade containment ring; the nacelle; and the high pressure turbine blades and vanes. The projected fuel savings resulting from the application of composites are 1.85 percent for the fan section, 1.75 percent for the nacelle, and 2.35 percent for the high pressure turbine. Author

**N77-13085\*** National Aeronautics and Space Administration, Lewis Research Center, Cleveland, Ohio.  
**INTERIM PREDICTION METHOD FOR TURBINE NOISE**  
Eugene A. Krejsa and Michael F. Valerino, Nov. 1976 25 p refs (NASA-TM-X-73566, E-9015) Avail NTIS HC A02/MF A01 CSDL 21E

A turbine noise prediction method for interim use in the NASA Aircraft Noise Prediction Program is selected. The method predicts the level, directivity, and one-third octave band spectra of far field turbine noise as a function of engine parameters. The selection results from a review of turbine noise data and prediction methods available in the open literature. It is concluded that the state-of-the-art turbine noise prediction capability is primitive and that the selected method represents only a temporary interim approach. Recommendations are made on research requirements. Author

**N77-14025\*** National Aeronautics and Space Administration, Lewis Research Center, Cleveland, Ohio.  
**DUAL OUTPUT VARIABLE PITCH TURBOFAN ACTUATION SYSTEM Patent**  
Robert H. Griswold, Jr. (GE, Cincinnati) and Carl L. Broman, inventors (to NASA) (GE, Cincinnati) Issued 30 Nov. 1976 10 p Filed 21 May 1975 Sponsored by NASA (NASA-Case-LEW-12419-1; US-Patent-3,994,128; US-Patent-Appl-SN-679375; US-Patent-Class-60-226R; US-Patent-Class-416-160; US-Patent-Class-416-162; US-Patent-Class-416-166; US-Patent-Class-416-167; US-Patent-Class-416-163) Avail US Patent Office CSDL 21E

An improved actuating mechanism was provided for a gas turbine engine incorporating fan blades of the variable pitch variety. The actuator adapted to rotate the individual fan blades within apertures in an associated fan disc. The actuator included means such as a pair of synchronizing ring gears, one on each side of the blade shanks, and adapted to engage pinions disposed thereon. Means were provided to impart rotation to the ring gears in opposite directions to effect rotation of the blade shanks in response to a predetermined input signal. In the event of system failure, a run-away actuator was prevented by an improved braking device which arrests the mechanism. Official Gazette of the U.S. Patent Office

**N77-14031\*** National Aeronautics and Space Administration, Lewis Research Center, Cleveland, Ohio.  
**SMALL, LOW COST, EXPENDABLE TURBOJET ENGINE. 2: PERFORMANCE CHARACTERISTICS**  
Robert P. Dangler and Lawrence E. Maciocce, Washington, Dec. 1976 31 p refs (NASA-TM-X-3463, E-8775) Avail NTIS HC A03/MF A01 CSDL 21E

A small experimental axial-flow turbojet engine was tested at sea level static conditions and over a range of simulated flight conditions to evaluate its performance as well as to demonstrate the feasibility of low-cost concepts utilized in its design. Testing was conducted at engine speeds as high as 37,000 rpm and at turbine inlet temperatures as high as 1,272 K. For maximum speed the engine produced a net thrust of 3.118 newtons at sea level static operation and 2.318 newtons at its cruise condition of MO = 0.8 and 6,096 meters. Data obtained over a range of inlet Reynolds number indexes for nominal MO of 0.38 revealed similar effects or trends on compressor characteristics of those previously established for much larger engines. Author

**N77-14032\*** National Aeronautics and Space Administration, Lewis Research Center, Cleveland, Ohio.  
**EFFECT OF EXHAUST GAS RECIRCULATION ON EMISSIONS FROM A FLAME-TUBE COMBUSTOR USING LIQUID JET A FUEL**  
Cecil J. Marek and Robert R. Tacina, Washington, Dec. 1976 28 p refs (NASA-TM-X-3464, E-8803) Avail NTIS HC A03/MF A01 CSDL 21E

The effects of uncooled exhaust gas recirculation as an inert diluent on emissions of oxides of nitrogen (NO + NO<sub>2</sub>) and on combustion efficiency were investigated. Ratios of recirculated combustion products to inlet airflow were varied from 10 to 80 percent by using an inlet air ejector nozzle. Liquid Jet A fuel was used. The flame-tube combustor was 10.2 cm in diameter. It was operated with and without a flameholder present. The combustor pressure was maintained constant at 0.5 MPa. The equivalence ratio was varied from 0.3 to 1.0. The inlet air temperature was varied from 590 to 800 K, and the reference velocity from 10 to 30 m/sec. Increasing the percent recirculation from 10 to 25 had the following effects: (1) the peak NOx emission was decreased by 37 percent, from 8 to 5 g NO<sub>2</sub>/kg fuel, at an inlet air temperature of 590 K and a reference velocity of 15 m/sec, (2) the combustion efficiency was increased, particularly at the higher equivalence ratios, and (3) for a high combustion efficiency of greater than 99.5 percent, the range of operation of the combustor was nearly doubled in terms of equivalence ratio. Increasing the recirculation from 25 to 50 percent did not change the emissions significantly. Author

**N77-18037\*** National Aeronautics and Space Administration.  
Lewis Research Center, Cleveland, Ohio.

**EFFECT OF CERAMIC COATING OF JT8D COMBUSTOR LINER ON MAXIMUM LINER TEMPERATURES AND OTHER COMBUSTOR PERFORMANCE PARAMETERS**  
Helmut E. Butze and Curt H. Liebert Dec. 1976 24 p refs  
(NASA-TM-X-73581; E-9043) Avail: NTIS HC A02/MF A01  
CSCL 21E

The effect of ceramic coating of a JT8D combustor liner was investigated at simulated cruise and takeoff conditions with two fuels of widely different aromatic contents. Substantial decreases in maximum liner temperatures and flame radiation values were obtained with the ceramic-coated liner. Small reductions in exhaust gas smoke concentrations were observed with the ceramic-coated liner. Other performance parameters such as combustion efficiency and emissions of unburned hydrocarbons, CO, and NOx were not affected significantly. No deterioration of the ceramic coating was observed after about 6 hours of cyclic operation including several startups and shutdowns. Author

**N77-17059\*** National Aeronautics and Space Administration.  
Lewis Research Center, Cleveland, Ohio.

**REVERSE PITCH FAN WITH DIVIDED SPLITTER Patent**  
Leroy H. Smith, Jr. (inventor (to NASA) (GE, Cincinnati, Ohio)  
Issued 1 Feb. 1977 6 p Filed 21 Apr 1975 Sponsored by NASA

(NASA-Case-LEW-12760-1; US-Patent-4,005,574;  
US-Patent-Appl-SN-569925; US-Patent-Class-60-226A;  
US-Patent-Class-60-228) Avail: US Patent Office CSCL 21E

A guide vane arrangement is described for improving gas turbine performance in the reverse thrust mode. This flow straightening method produces low losses in the fluid entering a core engine during reverse thrust operations and allows large supercharging of the core engine during forward thrust.

Official Gazette of the U.S. Patent Office

**N77-17082\*** National Aeronautics and Space Administration.  
Lewis Research Center, Cleveland, Ohio.

**FLIGHT EFFECTS ON EXHAUST NOISE FOR TURBOJET AND TURBOFAN ENGINES. COMPARISON OF EXPERIMENTAL DATA WITH PREDICTION**

James R. Stone 1976 21 p refs Presented at 92d Meeting of Acoustical Soc. of Am. San Diego, Calif. 16-19 Nov 1976  
(NASA-TM-X-73562; E-8990) Avail: NTIS HC A02/MF A01  
CSCL 20A

It was demonstrated that static and in flight jet engine exhaust noise can be predicted with reasonable accuracy when the multiple source nature of the problem is taken into account. Jet mixing noise was predicted from the interim prediction method. Provisional methods of estimating internally generated noise and shock noise flight effects were used, based partly on existing prediction methods and partly on recent reported engine data. Author

**N77-17063\*** National Aeronautics and Space Administration.  
Lewis Research Center, Cleveland, Ohio.

**PREDICTION OF LAMINAR AND TURBULENT BOUNDARY LAYER FLOW SEPARATION IN V-STOL ENGINE INLETS**  
D. C. Chou (Iowa Univ.), R. W. Ludens, and N. O. Stockman  
1977 16 p refs Presented at 15th Aerospace Sci. Conf. Los Angeles, 24-26 Jan. 1977, sponsored by AIAA  
(NASA-TM-X-73575; E-9028) Avail: NTIS HC A02/MF A01  
CSCL 21E

A description is presented of the development of the boundary layer on the lip and diffuser surface of a subsonic inlet at arbitrary operating conditions of mass flow rate, free stream velocity and incidence angle. Both laminar separation on the lip and turbulent separation in the diffuser are discussed. The agreement of the theoretical results with model experimental data illustrates the capability of the theory to predict separation. The effects of throat Mach number, inlet size, and surface roughness on boundary layer development and separation are illustrated. Author

**N77-17064\*** National Aeronautics and Space Administration.  
Lewis Research Center, Cleveland, Ohio.

**CORE NOISE MEASUREMENTS ON A YF-102 TURBOFAN ENGINE**

Meyer Reshotko, Allen Karchmar, Paul F. Ponko, and Jack G. McArdle 1977 27 p refs Presented at 15th Aerospace Sci. Meeting, Los Angeles, 24-26 Jan. 1977, sponsored by AIAA  
(NASA-TM-X-73587; E-9050) Avail: NTIS HC A03/MF A01  
CSCL 20A

Core noise from a YF-102 high bypass ratio turbofan engine was investigated through the use of simultaneous measurements of internal fluctuating pressures and far field noise. Acoustic waveguide probes, located in the engine at the compressor exit, in the combustor, at the turbine exit, and in the core nozzle, were employed to measure internal fluctuating pressures. Spectra showed that the internal signals were free of tones, except at high frequency where machinery noise was present. Data obtained over a wide range of engine conditions suggest that below 60% of maximum fan speed the low frequency core noise contributes significantly to the far field noise. Author

**N77-17065\*** National Aeronautics and Space Administration.  
Lewis Research Center, Cleveland, Ohio.

**FLAP NOISE AND AERODYNAMIC RESULTS FOR MODEL QCSSE OVER-THE-WING CONFIGURATIONS**

W. Olsen, R. Burns, and D. Groesbeck 1977 26 p refs  
Presented at 15th Aerospace Sci. Meeting, Los Angeles, 24-26 Jan. 1977, sponsored by AIAA  
(NASA-TM-X-73588; E-9051) Avail: NTIS HC A03/MF A01  
CSCL 21E

Noise spectra in three dimensions and aerodynamic data were measured for a model of the NASA quiet clean short-haul experimental engine (QCSSE) over-the-wing configuration. The effects of flap length, nozzle exhaust velocity and nozzle geometry were determined using a single nozzle and wing-flap segment. The scaled-up model data is representative of full scale flap noise with the QCSSE engine. Author

**N77-17066\*** National Aeronautics and Space Administration.  
Lewis Research Center, Cleveland, Ohio.

**COMPOSITE HUBS FOR LOW COST GAS TURBINE ENGINES**

C. C. Chemis 1977 14 p refs Presented at the 32d Annual Conf. of the Reinforced Plastics and Composites Inst., Washington, D. C. 8-11 Feb. 1977, sponsored by the Soc. of the Plastics Ind.  
(NASA-TM-X-73578; E-9038) Avail: NTIS HC A02/MF A01  
CSCL 21E

A detailed stress analysis was performed using NASTRAN to demonstrate theoretically the adequacy of composite hubs for low cost turbine engine applications. Composite hubs are adequate for this application from the steady state stress view point. Author

**N77-17067\*** National Aeronautics and Space Administration.  
Lewis Research Center, Cleveland, Ohio.

**EFFECT OF FLAME STABILIZER DESIGN ON PERFORMANCE AND EXHAUST POLLUTANTS OF A TWO-ROW SWIRL-CAN COMBUSTOR OPERATED TO NEAR-STOICHIOMETRIC CONDITIONS**

James A. Bigelow and Arthur M. Trout Feb. 1977 20 p refs  
(NASA-TM-X-73495; E-8317) Avail: NTIS HC A02/MF A01  
CSCL 21E

Emissions and performance characteristics were determined for two full annulus modular combustors operated to near stoichiometric fuel air ratios. The tests were conducted to obtain stoichiometric data at inlet air temperatures from 756 to 894 K and to determine the effects of a flat plate circular flame stabilizer with upstream fuel injection and a contraswirl flame stabilizer with downstream fuel injection. Levels of unburned hydrocarbons were below 0.50 gram per kilogram of fuel for both combustors and thus there was no detectable difference in the two methods of fuel injection. The contraswirl flame stabilizer did not produce the level of mixing obtained with a flat plate circular flame

stabilizer. It did produce higher levels of oxides of nitrogen, which peaked at a fuel air ratio of 0.037. For the flat plate circular flame stabilizer, oxides of nitrogen emission levels were still increasing with fuel air ratio to the maximum tested value of 0.045.  
Author

**N77-17070\*** National Aeronautics and Space Administration, Lewis Research Center, Cleveland, Ohio.  
**INTERNAL FLOW CHARACTERISTICS OF A MULTISTAGE COMPRESSOR WITH INLET PRESSURE DISTORTION**  
Claude E. DeBogdan, John E. Moss, Jr., and Willis M. Braithwaite  
Washington Feb. 1977 39 p refs  
(NASA-TM-X-3446; E-8848) Avail: NTIS HC A03/MF A01 CSCL 21E

The measured distribution of compressor interstage pressures and temperatures resulting from a 180 deg inlet-total-pressure distortion for a J85-13 turbojet engine is reported. Extensive inner stage instrumentation combined with stepwise rotation of the inlet distortion gave data of high circumferential resolution. The steady-state pressures and temperatures along with the amplitude, extent, and location of the distorted areas are given. Data for 80, 90, and 100 percent of rotor design speed are compared with clean (undistorted) inlet flow conditions to show pressure and temperature behavior within the compressor. Both overall and stage-wise compressor performances vary only slightly when clean and distorted inlet conditions are compared. Total and static pressure distortions increase in amplitude in the first few stages of the compressor and then attenuate fairly uniformly to zero at the discharge. Total-temperature distortion induced by the pressure distortion reached a maximum amplitude by the first two stages and decayed only a little through the rest of the compressor. Distortion amplitude tended to peak in line with the screen edges, and, except for total and static pressure in the tip zone, there was little swirl in the axial direction. Author

**N77-17081\*** National Aeronautics and Space Administration, Lewis Research Center, Cleveland, Ohio.  
**AIRCRAFT PISTON ENGINE EXHAUST EMISSION SYMPOSIUM**  
Sep 1976 373 p Symp held in Cleveland, 14-15 Sep. 1976  
(NASA-CP-2005; E-9010) Avail: NTIS HC A16/MF A01 CSCL 21E

A 2-day symposium on the reduction of exhaust emissions from aircraft piston engines was held on September 14 and 15, 1976, at the Lewis Research Center in Cleveland, Ohio. Papers were presented by both government organizations and the general aviation industry on the status of government contracts, emission measurement problems, data reduction procedures, flight testing, and emission reduction techniques. For individual titles, see N77-17082 through N77-17100.

**N77-17086\*** National Aeronautics and Space Administration, Lewis Research Center, Cleveland, Ohio.  
**SUMMARY REPORT ON EFFECTS AT TEMPERATURE, HUMIDITY, AND FUEL-AIR RATIO ON TWO AIR-COOLED LIGHT AIRCRAFT ENGINES**  
Erwin E. Kempke, Jr. In its Aircraft Piston Eng. Exhaust Emissions Symp. Sep. 1976 p 85-120 refs (For primary document see N77-17081 08-07)  
Avail: NTIS HC A16/MF A01 CSCL 21E

Five different engine models were tested to experimentally characterize emissions and to determine the effects of variation in fuel-air ratio and spark timing on emissions levels and other operating characteristics such as cooling, misfiring, roughness, power acceleration, etc. The results are given of two NASA reports covering the Avco Lycoming O-320-D engine testing and the recently obtained results on the Teledyne Continental TSIO-360-C engine.  
Author

**N77-17091\*** National Aeronautics and Space Administration, Lewis Research Center, Cleveland, Ohio.

# **INTRODUCTION TO NASA CONTRACTS**

Erwin E. Kempke, Jr. In its Aircraft Piston Eng. Exhaust Emissions Symp. Sep. 1976 p 225-226 (For primary document see N77-17081 08-07)

Avail: NTIS HC A16/MF A01 CSCL 21E

The NASA Lewis Research Center issued requests for proposal to Avco Lycoming and Teledyne Continental Motors for a contractual effort to establish and demonstrate engine modifications to reduce exhaust emissions safely with minimum adverse effects on cost, weight, and fuel economy. The secondary objective was reducing fuel consumption.  
Author

**N77-17096\*** National Aeronautics and Space Administration, Lewis Research Center, Cleveland, Ohio.

# **EMISSIONS AND NEW TECHNOLOGY PROGRAMS FOR CONVENTIONAL SPARK-IGNITION AIRCRAFT ENGINES**

William T. Wintucky In its Aircraft Piston Eng. Exhaust Emissions Symp. Sep. 1976 p 295-314 (For primary document see N77-17081 08-07)

Avail: NTIS HC A16/MF A01 CSCL 21E

A long-range technology plan in support of general aviation engines was formulated and is being implemented at the Lewis Research Center. The overall program was described, and that part of the program that represents the in-house effort at Lewis was presented in detail. Three areas of government and industry effort involving conventional general-aviation piston engines were part of a coordinated overall plan: (1) FAA/NASA joint program, (2) NASA contract exhaust emissions pollution reduction program, and (3) NASA in-house emissions reduction and new technology program.  
Author

**N77-17097\*** National Aeronautics and Space Administration, Lewis Research Center, Cleveland, Ohio.

# **ALTERNATIVE GENERAL-AIRCRAFT ENGINES**

William A. Tornazic In its Aircraft Piston Eng. Exhaust Emissions Symp. Sep. 1976 p 315-328 (For primary document see N77-17081 08-07)

Avail: NTIS HC A16/MF A01 CSCL 21E

The most promising alternative engine (or engines) for application to general aircraft in the post 1985 time period was defined, and the level of technology was cited to the point where confident development of a new engine can begin early in the 1980's. Low emissions, multifuel capability, and fuel economy were emphasized. Six alternative propulsion concepts were considered to be viable candidates for future general aircraft application: the advanced spark-ignition piston, rotary combustion, two- and four-stroke diesel, Stirling, and gas turbine engines.  
Author

**N77-18014\*** National Aeronautics and Space Administration, Lewis Research Center, Cleveland, Ohio.

# **COMPONENT TEST PROGRAM FOR VARIABLE-CYCLE ENGINES**

Albert G. Powers, John B. Whitlow, and Leonard E. Stitt In its Proc. of the SCAR Conf. Part 1 1976 p 371-385 refs (For primary document see N77-17996 09-01)  
Avail: NTIS HC A21/MF A01 CSCL 21E

**N77-18015\*** National Aeronautics and Space Administration, Lewis Research Center, Cleveland, Ohio.

# **SUPERSONIC CRUISE INLETS FOR VARIABLE-CYCLE ENGINES**

David N. Bowditch In its Proc. of the SCAR Conf. Part 1 1976 p 387-397 refs (For primary document see N77-17996 09-01)

Avail: NTIS HC A21/MF A01 CSCL 21E

**N77-18016\*** National Aeronautics and Space Administration.  
Lewis Research Center, Cleveland, Ohio.

**CONTROL OF PROPULSION SYSTEMS FOR SUPERSONIC CRUISE AIRCRAFT**

Kirby W. Miller and Daniel I. Drain. In its Proc. of the SCAR Conf., Part 1, 1976, p. 399-415. refs. (For primary document see N77-17996 09-01)

Avail. NTIS HC A21/MF A01 CSCL 21E

**N77-18018\*** National Aeronautics and Space Administration.  
Lewis Research Center, Cleveland, Ohio.

**COMPOSITE MATERIALS RESEARCH IN SUPPORT OF SUPERSONIC PROPULSION SYSTEMS**

Robert A. Signorilli. In its Proc. of the SCAR Conf., Part 1, 1976, p. 457-468. refs. (For primary document see N77-17996 09-01)

Avail. NTIS HC A20/MF A01 CSCL 21E

**N77-18024\*** National Aeronautics and Space Administration.  
Lewis Research Center, Cleveland, Ohio.

**TECHNOLOGY FOR CONTROLLING EMISSIONS OF OXIDES OF NITROGEN FROM SUPERSONIC CRUISE AIRCRAFT**

Gregory M. Rock and Richard A. Rudley. In its Proc. of the SCAR Conf., Pt. 2, 1976, 22 p. refs. (For primary document see N77-18019 09-01)

Avail. NTIS HC A23/MF A01 CSCL 21E

**N77-18157\*** National Aeronautics and Space Administration.  
Lewis Research Center, Cleveland, Ohio.

**COLD-AIR INVESTIGATION OF A 3 1/2-STAGE FAN-DRIVE TURBINE WITH A STAGE LOADING FACTOR OF 4 DESIGNED FOR AN INTEGRAL LIFT ENGINE. 2: PERFORMANCE OF 2-, 3- AND 3 1/2-STAGE CONFIGURATIONS**

Warren J. Whitney. Feb. 1977, 28 p. refs.  
(NASA-TM-X-3482, E-8874) Avail. NTIS HC A03/MF A01 CSCL 21E

The stage work distribution among the three stages was very close to the design value. The specific work output-mass flow characteristics of the three stages were closely matched. The efficiency of the 3 1/2 stage turbine at design specific work output and design speed was within 0.008 of the estimated value, and this agreement was felt to demonstrate the adequacy of the prediction method in the high stage loading factor regime. Author

**N77-18159\*** National Aeronautics and Space Administration.  
Lewis Research Center, Cleveland, Ohio.

**EFFECT OF ENDWALL COOLING ON SECONDARY FLOWS IN TURBINE STATOR VANES**

Louis J. Goldman and Kerry L. McLallin. 1977, 29 p. refs. Presented at AGARD 49th Propulsion and Energetics Panel Conf., The Hague, 28 Mar. - 4 Apr. 1977.  
(NASA-TM-X-73568) Avail. NTIS HC A03/MF A01 CSCL 21E

The effect of endwall cooling on the secondary flow behavior and the aerodynamic performance of a core turbine stator vane was determined. The investigation was conducted in a cold-air, full-annular cascade, where three-dimensional effects were obtained. Two endwall cooling configurations were tested. In the first configuration, the cooling holes were oriented so that the coolant was injected in line with the inviscid streamline direction. In the second configuration, the coolant was injected at an angle of 15 deg to the inviscid streamline direction and oriented towards the vane pressure stator. In both cases the stator vanes were solid and uncooled so that the effect of endwall cooling was obtained directly. Total-pressure surveys were taken downstream of the stator vanes over a range of cooling flows at the design, mean-radius, critical velocity ratio of 0.778. Changes in the total-pressure contours downstream of the vanes were used to obtain the effect of endwall cooling on the secondary flows in the stator. Author

**N77-18160\*** National Aeronautics and Space Administration.  
Lewis Research Center, Cleveland, Ohio.

**APPARATUS AND METHOD FOR REDUCING THERMAL STRESS IN A TURBINE ROTOR. Patent Application.**

J. A. Heller, inventor (to NASA). Filed 4 Mar. 1977, 13 p.  
(NASA-Case-LEW-12232-1; US-Patent-Appl-SN-776029) Avail. NTIS HC A02/MF A01 CSCL 21E

A gas turbine is provided wherein the thermal stresses in the turbine rotor are reduced. The rotor includes a central disc with a peripheral rim, and a plurality of blades extending radially outwardly from the rim, and to reduce thermal stresses, a duct arrangement is provided which selectively directs hot gases from the turbine combustor to the rim during the turbine start-up. The hot gases from the combustor serve to heat the rim and thus decrease the start-up period necessary to bring the temperature profile of the rotor into the operating temperature range. After the start-up period, the duct arrangement is then used to direct cool gases from the turbine compressor to the rim of the rotor in order to maintain a lower rotor equilibrium temperature. NASA

**N77-20106\*** National Aeronautics and Space Administration.  
Lewis Research Center, Cleveland, Ohio.

**OPTICAL DETECTION OF BLADE FLUTTER**

W. C. Nieboring and J. L. Pollack. 1977, 31 p. refs. Presented at Intern. Turbine Conf., Philadelphia, 27-31 Mar. 1977, sponsored by the Am. Soc. of Mech. Engr.

(NASA-TM-X-73573; E-9022) Avail. NTIS HC A03/MF A01 CSCL 21E

Dynamic strain gages mounted on rotor blades are used as the primary instrumentation for detecting the onset of flutter and defining the vibratory mode and frequency. Optical devices are evaluated for performing the same measurements as well as providing supplementary information on the vibratory characteristics. Two separate methods are studied: stroboscopic imagery of the blade tip and photoelectric scanning of blade tip motion. Both methods give visual data in real time as well as video tape records. The optical systems are described, and representative results are presented. The potential of this instrumentation in flutter research is discussed. Author

**N77-20109\*** National Aeronautics and Space Administration.  
Lewis Research Center, Cleveland, Ohio.

**DESIGN AND PERFORMANCE OF ENERGY EFFICIENT PROPELLERS FOR MACH 0.8 CRUISE**

Daniel C. Mikkelsen, Bernard J. Blaha, Glenn A. Mitchell, and Joseph E. Wiketa. 1977, 32 p. refs. Presented at the 1977 Natl. Business Aircraft Meeting and Exposition, Wichita, Kas. 29 Mar. - 1 Apr. 1977; sponsored by SAE Century 2.  
(NASA-TM-X-73612; E-9095; SAE-Paper-770458) Avail. NTIS HC A03/MF A01 CSCL 01C

The increased emphasis on fuel conservation in the world has stimulated a series of studies of both conventional and unconventional propulsion systems for commercial aircraft. Preliminary results from these studies indicate that a fuel saving of 14 to 40 percent may be realized by the use of an advanced high-speed turboprop. This turboprop must be capable of high efficiency at Mach 0.8 cruise above 9,144 km altitude if it is to compete with turbofan powered commercial aircraft. Several advanced aerodynamic concepts were investigated in recent wind tunnel tests under NASA sponsorship on two propeller models. These concepts included aerodynamically integrated propeller/nacelles, area ruling, blade sweep, reduced blade thickness and power (disk) loadings several times higher than conventional designs. The aerodynamic design methodology for these models is discussed. In addition, some of the preliminary test results are presented which indicate that propeller net efficiencies near 80 percent were obtained for high disk loading propellers operating at Mach 0.8. Author

**N77-20111\*** National Aeronautics and Space Administration.  
Lewis Research Center, Cleveland, Ohio.

**APPLICATION OF DIFFERENTIAL SIMILARITY TO FINDING  
NONDIMENSIONAL GROUPS IMPORTANT IN TESTS OF  
COOLED ENGINE COMPONENTS**

James Succi Washington Mar. 1977 36 p refs  
(NASA-TM-X-3484; E-8943) Avail: NTIS HC A03/MF A01  
CSCL 21E

The method of differential similarity is applied to the partial differential equations and boundary conditions which govern the temperature, velocity, and pressure fields in the flowing gases and the solid stationary components in air-cooled engines. This procedure yields the nondimensional groups which must have the same value in both the test rig and the engine to produce similarity between the test results and the engine performance. These results guide the experimentalist in the design and selection of test equipment that properly scales quantities to actual engine conditions. They also provide a firm fundamental foundation for substantiation of previous similarity analyses which employed heuristic, physical reasoning arguments to arrive at the nondimensional groups. Author

**N77-21087\*** National Aeronautics and Space Administration.  
Lewis Research Center, Cleveland, Ohio.

**A PRELIMINARY STUDY OF THE USE OF INTERCOOLING  
AND REHEAT IN CONJUNCTION WITH REGENERATION  
FOR AIRCRAFT TURBINE ENGINES**

Joseph D. Eisenberg Mar. 1977 39 p refs  
(NASA-TM-X-73617; E-9106) Avail: NTIS HC A03/MF A01  
CSCL 21E

The effect on fuel consumption of turbofans with intercooled, regenerative cycles and with intercooled, regenerative, reheat cycles was studied. The technology level for both engine and aircraft was that projected for 1985. The simulated mission was a 5556 km flight carrying 200 passengers at Mach 0.8 at 11582 min. Results indicate that these relatively complex cycles offer little, if any, fuel savings potential relative to a conventional turbofan cycle of comparable advanced technology. The intercooled, regenerative cycle yields about the same fuel economy as a conventional cycle at close to the same overall pressure ratio. Author

**N77-22118\*** National Aeronautics and Space Administration.  
Lewis Research Center, Cleveland, Ohio.

**VARIABLE-CYCLE ENGINES FOR SUPERSONIC CRUISE  
AIRCRAFT**

Edward Willis In AGARD Variable Geometry and Multicycle  
Eng. 1976 18 p refs (For primary document see N77-22112  
13-07)  
Avail: NTIS HC A20/MF A01

Variable cycle engine design concepts studied in terms of performance, economic, and environmental requirements that apply to modern supersonic cruise aircraft are described. The dual impact of design simplification and technology advancements is discussed along with advanced technology requirements in air and noise pollution reduction. J.M.S.

**N77-23108\*** National Aeronautics and Space Administration.  
Lewis Research Center, Cleveland, Ohio.

**OIL COOLING SYSTEM FOR A GAS TURBINE ENGINE  
Patent**

George A. Coffinberry (GE, Cincinnati) and Howard B. Kast.  
Inventors (to NASA) (GE, Cincinnati) Issued 3 May 1977 9 p  
Filed 4 Feb 1973 Division of US Patent Appl. SN-596641.  
filed 17 Jul 1975 Sponsored by NASA  
(NASA-Casa-LEW-12630-1; US-Patent-4,020,632)  
US-Patent-Appl-SN-655149; US-Patent-Class-60-39.03.  
US-Patent-Class-60-39.28R; US-Patent-Class-60-39.66.  
US-Patent-Class-415-181; US-Patent-Class-123-41.33.  
US-Patent-Class-123-17.E; US-Patent-Class-137-101.  
US-Patent-Appl-SN-596641) Avail: US Patent Office CSCL  
21E

A gas turbine engine fuel delivery and control system is provided with means to recirculate all fuel in excess fuel control

requirements back to the aircraft fuel tank. This increases the fuel pump heat sink and decreases the pump temperature rise without the addition of valving other than normally employed. A fuel/oil heat exchanger and associated circuitry is provided to maintain the hot engine oil in heat exchange relationship with the cool engine fuel. Where anti-icing of the fuel filter is required, means are provided to maintain the fuel temperature entering the filter at or above a minimum level to prevent freezing thereof. In one embodiment, a divider valve is provided to take all excess fuel from either upstream or downstream of the fuel filter and route it back to the tanks the ratio of upstream to downstream extraction being a function of fuel pump discharge pressure.

Official Gazette of the U.S. Patent Office

**N77-23109\*** National Aeronautics and Space Administration.  
Lewis Research Center, Cleveland, Ohio.

**NASA QUIET CLEAN GENERAL AVIATION TURBOFAN  
(QCGAT) PROGRAM STATUS**

D. L. Bresnahan and G. K. Sievers 1977 23 p Presented at  
Intern. Gas Turbine Conf., Philadelphia, Pa., 27-31 Mar 1977.  
sponsored by ASME  
(NASA-TM-X-73564; E-9008) Avail: NTIS HC A02/MF A01  
CSCL 21E

The suitability of large engine technology to reduce noise, emissions, and fuel consumption of small turbine engines and develop new technology where required is determined. The design, fabrication, assembly, test, and delivery of the experimental engines to NASA are discussed. Author

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**ANALYSIS OF CONTROL CONCEPTS FOR GAS AND  
SHAFT-COUPLED V-STOL AIRCRAFT LIFT FAN SYSTEMS**

James F. Sellers, Clint E. Hart and James R. Mihalcew 1977  
21 p refs Presented at V-STOL Conf. Palo Alto, Calif., 6-8 Jun  
1977, sponsored by AIAA  
(NASA-TM-X-73611; E-9094) Avail: NTIS HC A02/MF A01  
CSCL 21E

For lift fan powered V-STOL aircraft, two unconventional propulsion system types were proposed. The first type uses fans connected by hot gas ducting and the second type uses fans connected by cross shafting. An analytical study identified the basic steady-state and dynamic characteristics for each type of system. For the gas-coupled system, the control concepts analyzed were variable-area fan turbines and throttling valves in the ducting. For the shaft coupled system, the control concepts analyzed were variable-pitch fans and variable fan inlet guide vanes. All of these concepts are capable of meeting V-STOL aircraft control moment and transient response requirements when appropriate propulsion controls are used. Author

**N77-23112\*** National Aeronautics and Space Administration.  
Lewis Research Center, Cleveland, Ohio.

**MINIMUM-TIME ACCELERATION OF AIRCRAFT TUR-  
BOFAN ENGINES**

Fred Teren 1977 16 p refs Presented at Joint Automatic  
Control Conf., San Francisco, 22-24 Jun 1977  
(NASA-TM-X-73624; E-9115) Avail: NTIS HC A02/MF A01  
CSCL 21E

Minimum time accelerations of the F100 turbofan engine are presented. A piecewise-linear engine model, having three state variables and four control variables, is used to obtain the minimum-time solutions. The linear model which applies at a given time in the trajectory is determined by calculating a normalized distance from the current state to the equilibrium state associated with each linear model. The linear model associated with the closest equilibrium point is then used. The control histories for the minimum-time solutions are used as input to a nonlinear simulation of the F100 engine to verify the accuracy of the piecewise linear solutions. Author



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**STALLED AND STALL-FREE PERFORMANCE OF AXIAL-FLOW COMPRESSOR STAGE WITH THREE INLET-GUIDE-VANE AND STATOR-BLADE SETTINGS**

Donald C. Urasak, Ronald J. Steinke, and Walter S. Cunnam  
Washington May 1977 16 p refs  
(NASA-TN-D-8457; E-8222) Avail: NTIS HC A02/MF A01  
CSCL 21E

The performance of the first stage of a transonic, multistage compressor was mapped over a range of inlet-guide-vane and stator-blade settings. Both stall-free and deep-stall performance data were obtained. For the settings tested, as stall was encountered and flow was further reduced, a relatively sharp drop in pressure ratio occurred and was followed by a continuing but more gradual reduction in pressure ratio with reduced flow. The position of the stall line on the map of pressure ratio against equivalent weight flow was essentially unaffected over the range of inlet-guide-vane and stator-blade settings. Author

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**EMISSIONS AND TOTAL ENERGY CONSUMPTION OF A MULTICYLINDER PISTON ENGINE RUNNING ON GASOLINE AND A HYDROGEN-GASOLINE MIXTURE**

John F. Cassidy Washington May 1977 38 p refs  
(NASA-TN-D-8487; E-9705) Avail: NTIS HC A03/MF A01  
CSCL 21A

A multicylinder reciprocating engine was used to extend the efficient lean operating range of gasoline by adding hydrogen. Both bottled hydrogen and hydrogen produced by a research methanol steam reformer were used. These results were compared with results for all gasoline. A high-compression-ratio, displacement production engine was used. Apparent flame speed was used to describe the differences in emissions and performance. Therefore, engine emissions and performance, including apparent flame speed and energy lost to the cooling system and the exhaust gas, were measured over a range of equivalence ratios for each fuel. All emission levels decreased at the leaner conditions. Adding hydrogen significantly increased flame speed over all equivalence ratios. Author

**N77-24136\*** National Aeronautics and Space Administration, Lewis Research Center, Cleveland, Ohio.

**INLET REYNOLDS NUMBER AND TEMPERATURE EFFECTS ON THE STEADY-STATE PERFORMANCE OF A TFE731-2 TURBOFAN ENGINE**

George A. Bobula and Roy A. Lottig Washington May 1977 51 p refs Prepared in cooperation with the US Army Air Mobility R and D Lab., Cleveland  
(NASA-TM-X-3537; E-8941) Avail: NTIS HC A04/MF A01  
CSCL 21E

Effects of varying engine inlet Reynolds number index (0.75, 0.50, 0.25, and 0.12) and temperature (289 and 244 K) on a TFE731-2 turbofan engine were evaluated. Results were classified as either compression system effects or effects on overall performance. Standard performance maps are used to present compression system performance. Overall performance parameters are presented as a function of low rotor speed corrected to engine inlet temperature. Author

**N77-24138\*** National Aeronautics and Space Administration, Lewis Research Center, Cleveland, Ohio.

**ANALYTICAL PREDICTION OF THE PERFORMANCE AND STABILITY OF A J85-13 COMPRESSOR WITH DISTORTED INLET FLOW**

Edward J. Muner Washington May 1977 31 p refs  
(NASA-TM-X-3515; E-8887) Avail: NTIS HC A03/MF A01  
CSCL 21E

The parallel compressor concept was studied using a compressor model based on the overall clean-inlet performance map obtained from experimental tests in an altitude chamber using a General Electric J85-13 turbojet engine. The model, which includes a static-pressure balance calculation at compressor

discharge, was exercised at conditions corresponding to 10 different screen-induced distortion patterns included in the experimental data base. The spoiled area of these patterns ranged from 30 deg to 180 deg, and the distortion screen density, or the area blocked by the screen wire per unit area of screen, varied from 28 to 69 percent. The study indicates that at the higher corrected speeds, the analytical surge lines obtained are good representations of the corresponding experimental surge lines and are independent of distortion angle or distortion angle or distortion level. Author

**N77-24140\*** National Aeronautics and Space Administration, Lewis Research Center, Cleveland, Ohio.

**PERFORMANCE OF HIGH-AREA-RATIO ANNULAR DUMP DIFFUSER USING SUCTION-STABILIZED-VORTEX FLOW CONTROL**

Albert J. Juhasz and John M. Smith Washington May 1977 41 p refs  
(NASA-TM-X-3535; E-9011) Avail: NTIS HC A03/MF A01  
CSCL 21E

A short annular dump diffuser having a geometry conducive to formation of suction stabilized toroidal vortices in the region of abrupt area change was tested. The overall diffuser area ratio was 4.0 and the length to inlet height ratio was 2.0. Performance data were obtained at near ambient temperature and pressure for inlet Mach numbers of 0.18 and 0.30 with suction rates ranging from 0 to 18 percent of total inlet mass flowrate. Results show that the exit velocity profile could be readily biased toward either wall by adjustment of inner and outer wall suction rates. Symmetric exit velocity profiles were inherently unstable with a tendency to revert to a hub or tip bias. Diffuser effectiveness was increased from about 38 percent without suction to over 85 percent at a total suction rate of 10 to 12 percent. At the same time diffuser total pressure loss was reduced from 3.1 percent to 1.1 percent at an inlet Mach number of 0.3. Author

**N77-24141\*** National Aeronautics and Space Administration, Lewis Research Center, Cleveland, Ohio.

**NOISE OF FAN DESIGNED TO REDUCE STATOR LIFT FLUCTUATIONS**

James H. Dittmar, Richard P. Woodward, and Edward G. Stakolich Washington May 1977 47 p refs  
(NASA-TM-X-3538; E-8988) Avail: NTIS HC A03/MF A01  
CSCL 20A

An existing fan stage was redesigned to reduce stator lift fluctuations and was acoustically tested at three nozzle sizes for reduced noise generation. The lift fluctuations on the stator were reduced by increasing the stator cord, adjusting incidence angles, and adjusting the rotor velocity diagrams. Broadband noise levels were significantly reduced in the middle to high frequencies. Blade passage tone sound power was not lessened, but decreases in the harmonics were observed. Aerodynamic improvements in both performance and efficiency were obtained. Author

**N77-25174\*** National Aeronautics and Space Administration, Lewis Research Center, Cleveland, Ohio.

**EXPERIMENTAL APPARATUS FOR INVESTIGATION OF FAN AEROELASTIC INSTABILITIES IN TURBOMACHINERY**

William H. Jones, Walter A. Bishop, Thomas A. Kirchgessner, and John H. Dicus Washington Jun. 1977 32 p refs  
(NASA-TM-X-3508; E-9088) Avail: NTIS HC A03/MF A01  
CSCL 21E

The application, installation, and monitoring of dynamic strain gage instrumentation on the rotating fan blades for subsonic stalled flutter mode of the first fan rotor are described. The engine installation, the modifications to the engine controls to obtain off schedule operation of the fan, engine aerodynamic instrumentation, and general data acquisition systems are discussed. Author



**N77-28136\*** National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio.  
**DESIGN OF TURBOFAN ENGINE CONTROLS USING OUTPUT FEEDBACK REGULATOR THEORY**  
 Walter C. Merrill 1977 7 p refs Presented at the Joint Automatic Control Conf., San Francisco, 22-24 Jun. 1977 (NASA-TM-X-73622; E-9113) Avail: NTIS HC A02/MF A01 CSDL 21E

A multivariable control design procedure based on output feedback regulator (OFR) theory is applied to the F100 turbofan engine. Results for the OFR design are compared to a design based on linear quadratic regulator (LQR) theory. The OFR feedback control is designed in the full order state space and thus eliminates any need for model reduction techniques. Using the performance measure and control structure of the LQR design, an equivalent OFR feedback control is obtained. The flexibility of the OFR as a control design procedure is demonstrated, and differing feedback control structures are evaluated. Author

**N77-28137\*** National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio.  
**THE APPLICATION OF THE ROUTH APPROXIMATION METHOD TO TURBOFAN ENGINE MODELS**  
 Walter C. Merrill 1977 11 p refs Presented at the Joint Autom. Control Conf., San Francisco, 22-24 Jun. 1977 (NASA-TM-X-73623; E-9114) Avail: NTIS HC A02/MF A01 CSDL 21E

The Routh approximation technique is applied in the frequency domain to a 16th order state variable turbofan engine model. The results obtained motivate the extension of the frequency domain formulation of the Routh method to the time domain to handle the state variable formulation directly. The time domain formulation is derived, and a characterization, which specifies all possible Routh similarity transformations, is given. The characterization is computed by the solution of two eigenvalue eigenvector problems. The application of the time domain Routh technique to the state variable engine model is described, and some results are given. Author

**N77-27116\*** National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio.  
**BLADE RETAINER ASSEMBLY Patent**  
 George W. Luebering, inventor (to NASA) (GE, Cincinnati) Issued 5 Jul. 1977 7 p Filed 26 Apr. 1976 Sponsored by NASA (NASA-Case-LEW-12608-1; US-Patent-4,033,705; US-Patent-Appl-SN-680067; US-Patent-Class-416-220R; US-Patent-Class-416-221) Avail: US Patent Office CSDL 21E

A retaining assembly is provided for locking radially extending blades in a rotor disc associated with a gas turbine engine. The assembly includes a pair of spaced apart lugs axially extending from one side of the disc to form an access gap for insertion of a blade tang into a dovetail slot in the rotor disc. A pair of axially aligned inwardly facing recesses are disposed in the lugs. A retaining member resides in the recesses and extends across the gap to preclude egress of the blade tang from the dovetail slot. The retaining member includes at least one axially extending protrusion adapted to radially overlap and abuttingly engage a radially inwardly facing abutment surface on the lugs.

Official Gazette of the U.S. Patent Office

**N77-27117\*** National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio.  
**PRELIMINARY STUDY OF A HYDROGEN PEROXIDE ROCKET FOR USE IN MOVING SOURCE JET NOISE TESTS**  
 Robert M. Plencner [1977] 23 p ref (NASA-TM-X-73678; E-9210) Avail: NTIS HC A02/MF A01 CSDL 20A

A preliminary investigation was made of using a hydrogen peroxide rocket to obtain pure moving source jet noise data. The thermodynamic cycle of the rocket was analyzed. It was found that the thermodynamic exhaust properties of the rocket

could be made to match those of typical advanced commercial supersonic transport engines. The rocket thruster was then considered in combination with a streamlined ground car for moving source jet noise experiments. When a nonthrottling hydrogen peroxide rocket was used to accelerate the vehicle, propellant masses and/or acceleration distances became too large. However, when a throttling rocket or an auxiliary system was used to accelerate the vehicle, reasonable propellant masses could be obtained. Author

**N77-28118\*** National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio.  
**AERO-ACOUSTIC PERFORMANCE COMPARISON OF CORE ENGINE NOISE SUPPRESSORS ON NASA QUIET ENGINE C**  
 Harvey E. Bloomer and John W. Schaefer Jul. 1977 20 p refs Presented at the 13th Propulsion Conf., Orlando, Fla., 11-13 Jul. 1977; Cosponsored by the Am. Inst. of Aeron. and the Soc. of Automotive Engr. (NASA-TM-X-73662; E-9182) Avail: NTIS HC A02/MF A01 CSDL 21H

The relative aero-acoustic effectiveness of two core engine suppressors, a contractor-designed suppressor delivered with the Quiet Engine, and a NASA-designed suppressor was evaluated. The NASA suppressor was tested with and without a splitter making a total of three configurations being reported in addition to the baseline hardware case. The aerodynamic results are presented in terms of tailpipe pressure loss, corrected net thrust, and corrected specific fuel consumption as functions of engine power setting. The acoustic results are divided into duct and far-field acoustic data. The NASA-designed core suppressor did the better job of suppressing aft end noise, but the splitter associated with it caused a significant engine performance penalty. The NASA core suppressor without the splitter suppressed most of the core noise without any engine performance penalty. Author

**N77-28123\*** National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio.  
**FULL-SCALE ALTITUDE ENGINE TEST OF A TURBOFAN EXHAUST-GAS-FORCED MIXER TO REDUCE THRUST SPECIFIC FUEL CONSUMPTION**  
 Richard R. Culom and Roy L. Johnson Jul. 1977 31 p refs (NASA-TM-X-3568; E-9111) Avail: NTIS HC A03/MF A01 CSDL 21E

The specific fuel consumption of a low-bypass-ratio, confluent-flow, turbofan engine was measured with and without a mixer installed. Tests were conducted for flight Mach numbers from 0.3 to 1.4 and altitudes from 10,670 to 14,630 meters (35,000 to 48,000 ft) for core-stream-to-fan-stream temperature ratios of 2.0 and 2.5 and mixing-length-to-diameter ratios of 0.95 and 1.74. For these test conditions, the reduction in specific fuel consumption varied from 2.5 percent to 4.0 percent. Pressure loss measurements as well as temperature and pressure surveys at the mixer inlet, the mixer exit, and the nozzle inlet were made. Author

**N77-31182\*** National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio.  
**AERODYNAMIC AND DIRECTIONAL ACOUSTIC PERFORMANCE OF A SCOOP INLET**  
 John M. Abbott and Donald A. Dietrich Sep. 1977 28 p refs (NASA-TP-1028; E-9134) Avail: NTIS HC A03/MF A01 CSDL 21E

Aerodynamic and directional acoustic performances of a scoop inlet were studied. The scoop inlet is designed with a portion of the lower cowling extended forward to direct upward any noise that is propagating out the front of the engine toward the ground. The tests were conducted in an anechoic wind tunnel facility at free stream velocities of 0, 18, 41, and 61 m/sec and angles of attack from -10 deg to 120 deg. Inlet throat Mach number was varied from 0.30 to 0.75. Aerodynamically, at a free stream

velocity of 41 m/sec, the design throat Mach number (0.63), and an angle of attack of 50 deg, the scoop inlet total pressure recovery was 0.989 and the total pressure distortion was 0.15. The angles of attack where flow separation occurred with the scoop inlet were higher than those for a conventional symmetric inlet. Acoustically, the scoop inlet provided a maximum noise reduction of 12 to 15 db below the inlet over the entire range of throat Mach number and angle of attack at a free-stream velocity of 41 m/sec. Author

**N77-31163\*** National Aeronautics and Space Administration, Lewis Research Center, Cleveland, Ohio.  
**EFFECTS OF TEMPERATURE TRANSIENTS AT FAN INLET OF A TURBOFAN ENGINE**  
 Mahmood Abdelwahab Sep. 1977 40 p refs  
 (NASA-TP-1031; E-0162) Avail: NTIS HC A03/MF A01 CSCL 21E

The effects of fan inlet temperature transients on the performance and stability of a turbofan engine were determined. The experiment was conducted at 90 and 74 percent of low-pressure-rotor military speed (9525 rpm) and with fan inlet temperature distortions having circumferential extents of 90 deg, 180 deg, 270 deg, and 360 deg. Temperature transients were controlled by varying the magnitude and rate of change of the inlet temperature rise. The engine response ranged from a momentary compressor pressure disturbance to low-pressure-compressor stall. The compressor distortion limits decreased with decreasing low-pressure-rotor speed and increased with increasing circumferential extent of distortion. Analysis of the data suggests strongly that the distortion limits of the compressor are a function of a critical magnitude of inlet temperature rise and are independent of the temperature rise rate. Author

**N77-31164\*** National Aeronautics and Space Administration, Lewis Research Center, Cleveland, Ohio.  
**DEVELOPMENT AND VERIFICATION OF REAL-TIME, HYBRID COMPUTER SIMULATION OF F100-PW-100(3) TURBOFAN ENGINE**  
 John R. Sauch, Kurt Seldner, and David S. Cwynar Sep. 1977 75 p refs  
 (NASA-TP-1034; E-9090) Avail: NTIS HC A04/MF A01 CSCL 21E

A real time, hybrid computer simulation of a turbofan engine is described. Controls research programs involving that engine are supported by the simulation. The real time simulation is shown to match the steady state and transient performance of the engine over a wide range of flight conditions and power settings. The simulation equations, FORTRAN listing, and analog patching diagrams are included. Author

**N77-31165\*** National Aeronautics and Space Administration, Lewis Research Center, Cleveland, Ohio.  
**ADVANCED TURBOPROP TECHNOLOGY DEVELOPMENT**  
 J. F. Dugan, D. P. Bencze, and L. J. Williams 1977 39 p refs Presented at Aircraft Systems and Technol. Meeting, Seattle, 22-24 Aug. 1977; sponsored by AIAA  
 (NASA-TM-73729; E-9290) Avail: NTIS HC A03/MF A01 CSCL 21E

The efficiency of high-speed turboprop propulsion systems is considered with emphasis on fuel savings. Specific topics discussed include: (1) high efficiency and low noise of propeller design; (2) fuselage noise attenuation; (3) propeller and gear box maintenance; and (4) engine-airframe integration. J.M.S.

**N77-32148\*** National Aeronautics and Space Administration, Lewis Research Center, Cleveland, Ohio.  
**PLATFORM FOR A SWING ROOT TURBOMACHINERY BLADE Patent**  
 Richard Ravenhall, inventor (to NASA) (GE, Cincinnati) Issued 30 Aug. 1977 5 p Filed 3 Feb. 1976 Sponsored by NASA  
 (NASA-Case-LEW-12312-1; US-Patent-4,045,149; US-Patent-Appl-SN-654787; US-Patent-Class-416-135;

US-Patent-Class-416-190; US-Patent-Class-416-193A; US-Patent-Class-416-241A) Avail: US Patent Office CSCL 21E

A rotor apparatus, comprising a blade having a root adapted to swing laterally within a supporting spindle under impact loading, is provided with a flow path defining platform. The platform comprises an inner shroud extending generally laterally of the blade airfoil portion and adapted to swing laterally. In one embodiment, wherein the blade primarily comprises a laminate of composite filament plies, the inner shroud is bonded to the laminate. An outer shroud, fixed with respect to the supporting spindle, forms a lateral extension of the inner shroud with the blade in its normal operating position. The inner and outer shrouds are provided with a pair of complementary adjacent surfaces contoured to pass in relatively close-fitting relationships to each other when the blade swings under impact loadings.

Official Gazette of the U.S. Patent Office

**N77-32163\*** National Aeronautics and Space Administration, Lewis Research Center, Cleveland, Ohio.  
**EXPERIMENTAL FLOW COEFFICIENTS OF A FULL-COVERAGE FILM-COOLED-VANE CHAMBER**  
 Peter L. Meitner (Army Air Mobility Research and Development Lab., Cleveland, Ohio) and Steven A. Hippensteel Sep. 1977 31 p refs  
 (NASA-TP-1036; E-9146) Avail: NTIS HC A03/MF A01 CSCL 21E

Adjoint- and elevated-temperature flow tests were performed on a few times-actual-size model of an impingement- and film-cooled chamber of a core engine turbine vane. Tests were conducted with the impingement and film cooling plates combined to form a chamber and also with each of the individual separated plates. For the combined tests, the proximity of the film cooling plate affected the flow of coolant through the impingement plate, but not conversely. Impingement flow is presented in terms of a discharge coefficient, and the film cooling flow discharging into still air with no main stream gas flow is presented in terms of a total pressure-loss coefficient. The effects of main stream gas flow on discharge from the film cooling holes are evaluated as a function of coolant to main-stream gas momentum flux ratio. A smoothing technique is developed that identifies and helps reduce flow measurement data scatter. Author

**N77-32164\*** National Aeronautics and Space Administration, Lewis Research Center, Cleveland, Ohio.  
**EFFECT OF SLOTTED CASING TREATMENT WITH CHANGE IN REYNOLDS NUMBER INDEX ON PERFORMANCE OF A JET ENGINE**

John E. Moss, Jr. and Willis M. Braithwaite Sep. 1977 19 p refs  
 (NASA-TP-1058; E-9185) Avail: NTIS HC A02/MF A01 CSCL 21E

A tip-treated J85-13 engine was tested at Reynolds number indices (RNI) of 0.3 and 0.7 with a clean inlet for 80- and 100-percent corrected engine speeds. This engine was equipped with a compressor case which allowed changes to the case wall over the rotor tips of six of its eight stages. For all tests, the principal effects were (1) with tip treatment, a stall pressure ratio loss of 6 percent at 100 percent corrected engine speeds for both the 0.3 and 0.7 RNI, and (2) with and without tip treatment, decreasing the RNI from 0.7 to 0.3 decreased the stall pressure ratio 3.8 percent for 100 percent corrected engine speed and 2.8 percent for 80-percent corrected engine speed. Author

**N77-32165\*** National Aeronautics and Space Administration, Lewis Research Center, Cleveland, Ohio.  
**HIGH STIFFNESS SEALS FOR ROTOR CRITICAL SPEED CONTROL**  
 David P. Fleming Sep. 1977 25 p refs Presented at Vibrations Conf., Chicago, 26-29 Sep. 1977; sponsored by ASME  
 (NASA-TM-X-73654; E-9171) Avail: NTIS HC A02/MF A01 CSCL 21E

An annular seal is analyzed in which the inlet clearance is larger than the outlet clearance; the flow path may be either

stepped or tapered. This design produces radial stiffness 1.7 to 14 times that of a constant clearance seal having the same minimum clearance. When sealing high pressure fluids, such a seal improves rotor stability and can be used to shift troublesome critical speeds to a more suitable location. Author

**N77-32155\*** National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio.

**INTERACTION OF ROTOR TIP FLOW IRREGULARITIES WITH STATOR VANES AS A NOISE SOURCE**

James H. Dittmar Oct. 1977 14 p refs Presented at the 4th Aeroacoustics Conf., Atlanta, 3-5 Oct. 1977; sponsored by AIAA

(NASA-TM-73706) Avail: NTIS HC A02/MF A01 CSCL 21E

The role of the interaction of rotor tip flow irregularities (vortices and velocity defects) with downstream stator vanes is discussed as a possible fan noise mechanism. This is accomplished by: (1) indicating some of the methods of formation of these flow irregularities; (2) observing how they would behave with respect to known noise behavior; and (3) attempting to compare the strength of the rotor tip flow irregularity mechanism with the strength of the more common rotor wake-stator mechanism. The rotor tip flow irregularity-stator interaction is indicated as being a probable inflight noise source. Author

**N77-32157\*** National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio.

**EFFECTS OF SIMULATED FLIGHT ON FAN NOISE SUPPRESSION**

Marcus F. Heidmann and Donald A. Dietrich Oct. 1977 34 p refs Presented at 4th Aeroacoustics Conf., Atlanta, 3-5 Oct. 1977; sponsored by AIAA

(NASA-TM-73708; E-9247) Avail: NTIS HC A03/MF A01 CSCL 21E

Attenuation properties of three treated fan inlets were evaluated. Tunnel flow simulated the inflow clean-up effect on source noise observed in flight and allowed observation of the blade passage frequency tone cut-off phenomenon. Acoustic data consisted of isolated inlet noise measured in the far field at two fixed positions and with traverses at four frequencies. Attenuation and source noise properties with and without flight simulation are compared and discussed. Averaged attenuation properties showed relative agreement of the inlets with their design intent; however, tunnel flow significantly affected the attenuation spectra. Author

**N77-32158\*** National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio.

**ACOUSTIC PERFORMANCE OF INLET MULTIPLE-PURE-TONE SUPPRESSORS INSTALLED ON NASA QUIET ENGINE C**

Harry E. Bloomer, John W. Schaefer, Edward J. Rice, and Charles E. Feiler Oct. 1977 16 p refs Presented at 4th Aeroacoustics Conf., Atlanta, 3-5 Oct. 1977; sponsored by AIAA

(NASA-TM-73713) Avail: NTIS HC A02/MF A01 CSCL 21E

The length of multiple-pure-tone (MPT) treatment required to reasonably suppress the MPTs produced by a supersonic tip speed fan was defined. Other suppression, broadband, and blade passing frequency, which might be accomplished were also determined. The experimental results are presented in terms of both far-field and duct acoustic data. Author

**N77-32159\*** National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio.

**SUMMARY OF FORWARD VELOCITY EFFECTS ON FAN NOISE**

Charles E. Feiler and John F. Groeneweg Oct. 1977 16 p refs Presented at 4th Aeroacoustics Conf., Atlanta, 3-5 Oct. 1977; sponsored by AIAA

(NASA-TM-73722; E-9209) Avail: NTIS HC A02/MF A01 CSCL 20A

Available experimental data comparing the in-flight and static behavior of fan noise are reviewed. These results are then compared with recent data obtained for a fan stage tested with forward velocity in a low speed wind tunnel. Tentative conclusions are presented about the significance and nature of the changes in noise observed when a forward velocity is imposed. Finally, the implications of the emerging picture of in-flight fan source noise for suppressor design are discussed. Author

**N77-32160\*** National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio.

**MULTIMODAL FAR-FIELD ACOUSTIC RADIATION PATTERN: AN APPROXIMATE EQUATION**

Edward J. Rice Oct. 1977 12 p refs Presented at the Fourth Aeroacoustics Conf., Atlanta, 3-5 Oct. 1977; sponsored by AIAA

(NASA-TM-73721) Avail: NTIS HC A02/MF A01 CSCL 20A

The far-field sound radiation theory for a circular duct was studied for both single mode and multimodal inputs. The investigation was intended to develop a method to determine the acoustic power produced by turbofans as a function of mode cut-off ratio. With reasonable simplifying assumptions the single mode radiation pattern was shown to be reducible to a function of mode cut-off ratio only. With modal cut-off ratio as the dominant variable, multimodal radiation patterns can be reduced to a simple explicit expression. This approximate expression provides excellent agreement with an exact calculation of the sound radiation pattern using equal acoustic power per mode. Author

**N77-33150\*** National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio.

**PROGRESS IN ADVANCED HIGH TEMPERATURE TURBINE MATERIALS, COATINGS, AND TECHNOLOGY**

John C. Freche and G. Mervin Ault 23 Sep. 1977 44 p refs Presented at the 50th Panel on Propulsion and Energetics, Ankara, 19-23 Sep. 1977; sponsored by AGARD

(NASA-TM-X 73628) Avail: NTIS HC A03/MF A01 CSCL 21E

Material categories as well as coatings and recent turbine cooling developments are reviewed. Current state of the art is identified, and as assessment, when appropriate, of progress, problems, and future directions is provided. Author

**N77-33160\*** National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio.

**STEADY-STATE UNBALANCE RESPONSE OF A THREE-DISK FLEXIBLE ROTOR ON FLEXIBLE, DAMPED SUPPORTS**

Robert E. Cunningham 29 Sep. 1977 42 p refs Presented at the Vibrations Conf., Chicago, 28-29 Sep. 1977; sponsored by ASME

(NASA-TM-X-73688; E-9081-1) Avail: NTIS HC A03/MF A01 CSCL 21E

Experimental data are presented for the unbalance response of a flexible, ball bearing supported rotor to speeds above the third lateral bending critical. Values of squeeze film damping coefficients obtained from measured data are compared to theoretical values obtained from short bearing approximation over a frequency range from 5000 to 31000 cycles/min. Experimental response for an undamped rotor is compared to that of one having oil squeeze film dampers at the bearings. Unbalance applied varied from 0.62 to 15.1 gm-cm. Author

**N77-33161\*** National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio.

**OVER-THE-WING MODEL THRUST REVERSER NOISE TESTS**

J. Goodykoontz and O. Gutierrez 5 Oct. 1977 20 p refs Presented at the 4th Aeroacoustics Conf., Atlanta, 3-5 Oct. 1977; sponsored by AIAA

(NASA-TM-73495; E-9328) Avail: NTIS HC A02/MF A01

**CSCS 20A**

Static acoustic tests were conducted on a 1/12 scale model over-the-wing target type thrust reverser. The model configuration simulates a design that is applicable to the over-the-wing short-haul advanced technology engine. Aerodynamic screening tests of a variety of reverser designs identified configurations that satisfied a reverse thrust requirement of 35 percent of forward thrust at a nozzle pressure ratio of 1.29. The variations in the reverser configuration included, blocker door angle, blocker door lip angle and shape, and side skirt shape. Acoustic data are presented and compared for the various configurations. The model data scaled to a single full size engine show that peak free field perceived noise (PN) levels at a 152.4 meter sideline distance range from 98 to 104 PNdB. Author

**N77-33182\*** National Aeronautics and Space Administration, Lewis Research Center, Cleveland, Ohio.

**IDENTIFICATION AND MEASUREMENT OF COMBUSTION NOISE FROM A TURBOFAN ENGINE USING CORRELATION AND COHERENCE TECHNIQUES Ph.D. Thesis**

Allen Martin Karchmer Sep. 1977 156 p refs  
(NASA-TM-73747; E-9318) Avail: NTIS HC A08/MF A01 CSCS 20A

Fluctuating pressure measurements within the combustor and tailpipe of a turbofan engine are made simultaneously with far field acoustic measurements. The pressure measurements within the engine are accomplished with cooled semi-infinite waveguide probes utilizing conventional condenser microphones as the transducers. The measurements are taken over a broad range of engine operating conditions and for 16 far field microphone positions between 10 deg and 160 deg relative to the engine inlet axis. Correlation and coherence techniques are used to determine the relative phase and amplitude relationships between the internal pressures and far field acoustic pressures. The results indicate that the combustor is a low frequency source region for acoustic propagation through the tailpipe and out to the far field. Specifically, it is found that the relation between source pressure and the resulting sound pressure involves a 180 deg phase shift. The latter result is obtained by Fourier transforming the cross correlation function between the source pressure and acoustic pressure after removing the propagation delay time. Further, it is found that the transfer function between the source pressure and acoustic pressure has a magnitude approximately proportional to frequency squared. These results are shown to be consistent with a model using a modified source term in Lighthill's turbulence stress tensor, wherein the fluctuating Reynolds stresses are replaced with the pressure fluctuations due to fluctuating entropy. Author

**N77-33183\*** National Aeronautics and Space Administration, Lewis Research Center, Cleveland, Ohio.

**MEASUREMENT OF FAR FIELD COMBUSTION NOISE FROM A TURBOFAN ENGINE USING COHERENCE FUNCTIONS**

A. M. Karchmer, M. Reshetko, and F. J. Montagnani 5 Oct. 1977 33 p refs Presented at 4th Aeroacoustics Conf., Atlanta, 3-5 Oct. 1977; sponsored by AIAA  
(NASA-TM-73748; E-9320; AIAA-Paper-77-1277) Avail: NTIS HC A03/MF A01 CSCS 21E

Coherence measurements between fluctuating pressure in the combustor of a YF-102 turbofan engine and far-field acoustic pressure were made. The results indicated that a coherent relationship between the combustor pressure and far-field existed only at frequencies below 250 Hz, with the peak occurring near 125 Hz. The coherence functions and the far-field spectra were used to compute the combustor-associated far-field noise in terms of spectra, directivity, and acoustic power, over a range of engine operating conditions. The acoustic results so measured were compared with results obtained by conventional methods, as well as with various semiempirical predictions schemes. Examination of the directivity patterns indicated a peak in the combustion noise near 120 deg (relative to the inlet axis). Author

**N77-33184\*** National Aeronautics and Space Administration, Lewis Research Center, Cleveland, Ohio.

**IMPROVED COMPUTER PROGRAMS FOR CALCULATING POTENTIAL FLOW IN PROPULSION SYSTEM INLETS**

Norbert O. Stockman and Charles A. Farrell, Jr. Jul. 1977 430 p refs  
(NASA-TM-73728; E-9285) Avail: NTIS HC A18/MF A01 CSCS 21E

Computer programs to calculate the incompressible potential flow corrected for compressibility in axisymmetric inlets at arbitrary operating conditions are presented. Included are a statement of the problem to be solved, a description of each of the programs and sufficient documentation, including a test case, to enable a user to run the programs. Author

**N77-33185\*** National Aeronautics and Space Administration, Lewis Research Center, Cleveland, Ohio.

**OUTPUT FEEDBACK REGULATOR DESIGN FOR JET ENGINE CONTROL SYSTEMS**

Walter Merrill 1977 14 p refs Presented at Intern. Forum on Alternatives for Linear Multivariable Control, Chicago, 13-14 Oct. 1977; sponsored by Natl. Elec. Conf.  
(NASA-TM-73776) Avail: NTIS HC A02/MF A01 CSCS 21E

A multivariable control design procedure based on the output feedback regulator formulation is described and applied to turbofan engine model. Full order model dynamics, were incorporated in the example design. The effect of actuator dynamics on closed loop performance was investigated. Also, the importance of turbine inlet temperature as an element of the dynamic feedback was studied. Step responses were given to indicate the improvement in system performance with this control. Calculation times for all experiments are given in CPU seconds for comparison purposes. Author

**N77-33186\*** National Aeronautics and Space Administration, Lewis Research Center, Cleveland, Ohio.

**STATE-OF-THE-ART OF TURBOFAN ENGINE NOISE CONTROL**

W. L. Jones and J. F. Groeneweg Oct. 1977 22 p refs Presented at NOISE-CON 77, Hampton, Va., 17-19 Oct. 1977; cosponsored by Inst. of Noise Control Eng.  
(NASA-TM-73734; E-9254) Avail: NTIS HC A02/MF A01 CSCS 21E

The technology of turbofan engine noise reduction is surveyed. Specific topics discussed include: (1) new fans for low noise; (2) fan and core noise suppression; (3) turbomachinery noise sources; and (4) a new program for improving static noise testing of fans and engines. Author

**N77-33187\*** National Aeronautics and Space Administration, Lewis Research Center, Cleveland, Ohio.

**MINIMUM TIME ACCELERATION OF AIRCRAFT TURBOFAN ENGINES BY USING AN ALGORITHM BASED ON NONLINEAR PROGRAMMING**

Fred Teren Jul. 1977 182 p refs  
(NASA-TM-73741) Avail: NTIS HC A08/MF A01 CSCS 21E

Minimum time accelerations of aircraft turbofan engines are presented. The calculation of these accelerations was made by using a piecewise linear engine model, and an algorithm based on nonlinear programming. Use of this model and algorithm allows such trajectories to be readily calculated on a digital computer with a minimal expenditure of computer time. Author

**N77-33188\*** National Aeronautics and Space Administration, Lewis Research Center, Cleveland, Ohio.

**F100 MULTIVARIABLE CONTROL SYNTHESIS PROGRAM: EVALUATION OF A MULTIVARIABLE CONTROL USING A REAL-TIME ENGINE SIMULATION**

John R. Szuch, James F. Soeder, Kurt Seldner, and David S. Cwynar Oct. 1977 103 p refs  
(NASA-TP-1058; E-9170) Avail: NTIS HC A06/MF A01 CSCS 21E

The design, evaluation, and testing of a practical, multivariable, linear quadratic regulator control for the F100 turbofan engine were accomplished. NASA evaluation of the multivariable control logic and implementation are covered. The evaluation utilized a real time, hybrid computer simulation of the engine. Results of the evaluation are presented, and recommendations concerning future engine testing of the control are made. Results indicated that the engine testing of the control should be conducted as planned. **Author**

**A77-17246 \*** Status review of NASA programs for reducing aircraft gas turbine engine emissions. R. A. Rudey (NASA, Lewis Research Center, Cleveland, Ohio). In: International Symposium on Air Breathing Engines, 3rd, Munich, West Germany, March 7-12, 1976, Proceedings. (A77-17226 05-07) Cologne, Deutsche Gesellschaft für Luft- und Raumfahrt, 1976, p. 383-407, 19 refs.

The paper describes and discusses the results from some of the research and development programs for reducing aircraft gas turbine engine emissions. Although the paper concentrates on NASA programs only, work supported by other U.S. government agencies and industry has provided considerable data on low emission advanced technology for aircraft gas turbine engine combustors. The results from the two major NASA technology development programs, the ECCP (Experimental Clean Combustor Program) and the PRTP (Pollution Reduction Technology Program), are presented and compared with the requirements of the 1979 U.S. EPA standards. Emission reduction techniques currently being evaluated in these

programs are described along with the results and a qualitative assessment of development difficulty. **S.D.**

**A77-19981 \*** Core noise measurements on a YF-102 turbofan engine. M. Reshotko, A. Karchmer, P. F. Penko, and J. G. McArdle (NASA, Lewis Research Center, V/STOL and Noise Div., Cleveland, Ohio). *American Institute of Aeronautics and Astronautics, Aerospace Sciences Meeting, 15th, Los Angeles, Calif., Jan. 24-26, 1977, Paper 77-21, 27 p.* 7 refs.

Core noise from a YF-102 high bypass ratio turbofan engine was investigated through the use of simultaneous measurements of internal fluctuating pressures and far field noise. Acoustic waveguide probes, located in the engine at the compressor exit, in the combustor, at the turbine exit, and in the core nozzle, were employed to measure internal fluctuating pressures. Spectra showed that the internal signals were free of tones, except at high frequency where machinery noise was present. Data obtained over a wide range of engine conditions suggest that below 60% of maximum fan speed the low frequency core noise contributes significantly to the far field noise. **(Author)**

**A77-26396 \*** Opportunities for ceramics in the ERDA/NASA Continuous Combustion Propulsion Systems Program. C. P. Blankenship (NASA, Lewis Research Center, Cleveland, Ohio) and R. B. Schulz (ERDA, Transportation Energy Conservation Div., Cleveland, Ohio). *Energy Research and Development Administration, Workshop on Ceramics for Energy Conversion Systems, Orlando, Fla., Jan. 24-27, 1977, Paper, 5 p.*

The ERDA/NASA Continuous Combustion Highway Vehicles Program is concerned with the development of improved automotive powerplants. Specific program goals are related to an achievement of an improved fuel economy, low emissions, multifuel capability, and marketability. An employment of high temperature ceramic materials is considered in connection with the development of improved gas turbine and Stirling engines. The ceramic materials technology project is discussed, taking into account the characterization of ceramic materials, improved ceramic materials, and questions of component design, fabrication, and testing. **G.R.**

**A77-28220 \*** The impact of emission standards on the design of aircraft gas turbine engine combustors. R. A. Rudey (NASA, Lewis Research Center, Cleveland, Ohio). *Society of Automotive Engineers, Aerospace Engineering and Manufacturing Meeting, San Diego, Calif., Nov. 29-Dec. 2, 1976, Paper 760909, 14 p.* 14 refs.

The advent of environmental standards for controlling aircraft gas turbine engine emissions has led to a reevaluation of combustor design techniques. Effective emission control techniques have been identified and a wide spectrum of potential applications for these techniques to existing and advanced engines are being considered. Results from advanced combustor concept evaluations and from fundamental experiments are presented and discussed and comparisons are made with existing EPA emission standards and recommended levels for high altitude cruise. The impact that the advanced low emission concepts may impose on future aircraft engine combustor designs and related engine components is discussed. **(Author)**

**A77-28226 \*** Cyclic structural analyses of air-cooled gas turbine blades and vanes. A. Kaufman and R. E. Gaugler (NASA, Lewis Research Center, Cleveland, Ohio). *Society of Automotive Engineers, Aerospace Engineering and Manufacturing Meeting, San Diego, Calif., Nov. 29-Dec. 2, 1976, Paper 760918, 15 p.* 16 refs.

The creep-fatigue behavior of a fully impingement-cooled blade for four cyclic cases was analyzed by using the Elas 55, finite-element, nonlinear structural computer program. Expected cyclic lives were calculated by using the method of Strainrange Partitioning for reversed inelastic strains and time fractions for ratcheted tensile creep strains. Strainrange Partitioning was also applied to previous results from a one-dimensional cyclic analysis of a film-impingement-cooled vane. The analyses indicated that Strainrange Partitioning is more applicable to a constrained airfoil such as the film-impingement-cooled vane than to the relatively unconstrained fully impingement-cooled airfoil. **(Author)**

**A77-28577 \*** Optical detection of blade flutter. W. C. Nieberding and J. L. Pollack (NASA, Lewis Research Center, Cleveland, Ohio). *American Society of Mechanical Engineers, Gas Turbine Conference and Products Show, Philadelphia, Pa., Mar. 27-31, 1977, Paper 77-GT-66, 10 p.* Members, \$1.50; nonmembers, \$3.00.

The paper examines the capabilities of photoelectric scanning (PES) and stroboscopic imagery (SI) as optical monitoring tools for detection of the onset of flutter in the fan blades of an aircraft gas turbine engine. Both optical techniques give visual data in real time as well as video-tape records. PES is shown to be an ideal flutter monitor, since a single cathode ray tube displays the behavior of all the blades in a stage simultaneously. Operation of the SI system continuously while searching for a flutter condition imposes severe demands on the flash tube and affects its reliability, thus limiting its use as a flutter monitor. A better method of operation is to search for flutter with the PES and limit the use of SI to those times when the PES indicates interesting blade activity. **S.D.**

**A77-28588 \*** NASA Quiet, Clean General Aviation Turbofan (QCGAT) program status. D. L. Bresnahan and G. K. Sievers (NASA, Lewis Research Center, Cleveland, Ohio). *American Society of Mechanical Engineers, Gas Turbine Conference and Products Show, Philadelphia, Pa., Mar. 27-31, 1977, Paper 77-GT-77, 8 p.* Members, \$1.50; nonmembers, \$3.00.

Emissions pollution studies, noise studies, and engine performance studies and their place in QCGAT developmental program status are reported. The Lycoming TFE 731 turbofan engine, the GE T700-GE-700 high bypass ratio turbofan, and the AVCO-Lycoming LTS 101 turboshaft engine are prominent candidates in the tests for urban quiet turbofan service. Two phases in the program are characterized. Engine quieting, polluting emissions abatement, and

fuel economies are particularly important for the anticipated rise in number of jet propulsion craft using smaller airports adjacent to communities accustomed to low noise/pollution backgrounds. R.D.V.

**A77-28607 \* #** Altitude engine test of a turbofan exhaust gas mixer to conserve fuel. R. R. Cullom and R. L. Johnson (NASA, Lewis Research Center, Cleveland, Ohio). *American Society of Mechanical Engineers, Gas Turbine Conference and Products Show, Philadelphia, Pa., Mar. 27-31, 1977, Paper 77-GT-97*, 5 p. Members, \$1.50; nonmembers, \$3.00.

A comparison of the specific fuel consumption was made with and without an internal mixer installed in a low bypass ratio, confluent flow turbofan engine. Tests were conducted at several Mach numbers and altitudes for core to fan stream total temperature ratios of 2.0 and 2.5 and mixing lengths of  $L/D = 0.95$  and 1.74. For these test conditions, the specific fuel consumption improvement varied from 2.5 to 4.0 percent. (Author)

**A77-28630 \*** Simulation of a turbofan engine for evaluation of multivariable optimal control concepts. K. Seldner (NASA, Lewis Research Center, Cleveland, Ohio). In: *Productivity: Proceedings of the Joint Automatic Control Conference, West Lafayette, Ind., July 27-30, 1976*. (A77-28626 12-63) New York, American Society of Mechanical Engineers, 1976, p. 117-123.

This paper describes the development and use of a real-time simulation of the F100-PW-100 turbofan engine. The simulation is being used in a multi-variable optimal controls research program using linear quadratic regulatory theory. The simulation is used to generate linear engine models at selected operating points and evaluate the control algorithm. The paper discusses a technique to reduce the order of the model and compares selected results between high and low order models. (Author)

**A77-32239 \* #** Effect of endwall cooling on secondary flows in turbine stator vanes. L. J. Goldman and K. L. McLallin (NASA, Lewis Research Center, Cleveland, Ohio). *NATO, AGARD, Propulsion and Energetics Panel Conference, 49th, The Hague, Netherlands, Mar. 28-Apr. 4, 1977, Paper*, 28 p. 9 refs.

An experimental investigation was performed to determine the effect of endwall cooling on the secondary flow behavior and the aerodynamic performance of a core-turbine stator vane. The investigation was conducted in a cold-air, full-annular cascade, where three-dimensional effects could be obtained. In one configuration, the cooling holes were oriented so that the coolant was injected in line with the inviscid streamline direction. In another configuration, the coolant was injected at an angle of 15 deg to the inviscid streamline direction and oriented toward the vane pressure surface. Total-pressure surveys were taken downstream of the stator vanes over a range of cooling flows. Changes in the total-pressure contours downstream of the vanes were used to obtain the effect of endwall cooling on the secondary flows in the stator. Comparisons are made between the two cooled-endwall configurations and with the results obtained previously for solid (uncooled) endwalls. (Author)

**A77-37077 \* #** Design and performance of energy efficient propellers for Mach 0.8 cruise. D. C. Mikkelsen, B. J. Blaha, G. A. Mitchell, and J. E. Wikete (NASA, Lewis Research Center, Cleveland, Ohio). *Society of Automotive Engineers, Business Aircraft Meeting, Wichita, Kan., Mar. 29-Apr. 1, 1977, Paper 770458*, 29 p. 26 refs.

It is believed that a fuel saving of 14 to 40 percent may be realized by the use of an advanced high-speed turboprop. This turboprop must be capable of high efficiency at Mach 0.8 cruise above 9.144 km altitude if it is to compete with turbofan powered commercial aircraft. Several advanced aerodynamic concepts were investigated in recent wind tunnel tests under NASA sponsorship on two propeller models. These concepts included aerodynamically integrated propeller/nacelles, area ruling, blade sweep, reduced blade

thickness and power (disk) loadings several times higher than conventional designs. The aerodynamic design methodology for these models is discussed in this paper. In addition, some of the preliminary test results are presented which indicate that propeller net efficiencies near 80 percent were obtained for high disk loading propellers operating at Mach 0.8. (Author)

**A77-38652 \* #** Evaluation of an F100 multivariable control using a real-time engine simulation. J. R. Szuch, J. F. Soeder (NASA, Lewis Research Center, Cleveland, Ohio), and C. Skira (USAF, Aero Propulsion Laboratory, Wright-Patterson AFB, Ohio). *American Institute of Aeronautics and Astronautics and Society of Automotive Engineers, Propulsion Conference, 13th, Orlando, Fla., July 11-13, 1977, AIAA Paper 77-835*, 13 p. 16 refs.

The control evaluated has been designed for the F100-PW-100 turbofan engine. The F100 engine represents the current state-of-the-art in aircraft gas turbine technology. The control makes use of a multivariable, linear quadratic regulator. The evaluation procedure employed utilized a real-time hybrid computer simulation of the F100 engine and an implementation of the control logic on the NASA LoRC digital computer/controller. The results of the evaluation indicated that the control logic and its implementation will be capable of controlling the engine throughout its operating range. G.R.

**A77-38668 \* #** Atmospheric effects on inlets for supersonic cruise aircraft. G. L. Cole (NASA, Lewis Research Center, Wind Tunnel and Flight Div., Cleveland, Ohio). *American Institute of Aeronautics and Astronautics and Society of Automotive Engineers, Propulsion Conference, 13th, Orlando, Fla., July 11-13, 1977, AIAA Paper 77-874*, 11 p. 12 refs.

Time response effects of atmospheric-type disturbances on inlets and some implications regarding inlet controls are considered. A study involving the simulation of a mixed-compression inlet is described. The study employs a linear dynamic analysis, modified for a significant nonlinearity. Transient disturbances in ambient temperature and pressure and wind gusts are considered independently at the inlet cruise Mach number of 2.5. The presented results show the maximum amplitude of a triangular-wave disturbance, that does not cause inlet unstart, as a function of disturbance pulse width. G.R.

**A77-38597 \* #** Aero-acoustic performance comparison of core engine noise suppressors on NASA quiet engine 'C'. H. E. Bloomer and J. W. Schaefer (NASA, Lewis Research Center, Cleveland, Ohio). *American Institute of Aeronautics and Astronautics and Society of Automotive Engineers, Propulsion Conference, 13th, Orlando, Fla., July 11-13, 1977, AIAA Paper 77-922*, 14 p. 15 refs.

The purpose of the experimental program reported herein was to evaluate and compare the relative zero-acoustic effectiveness of two core engine suppressors, a contractor-designed suppressor delivered with the Quiet Engine, and a NASA-designed suppressor, designed and built subsequently. The NASA suppressor was tested with and without a splitter making a total of three configurations being reported in addition to the baseline hardware case. The aerodynamic results are presented in terms of tailpipe pressure loss, corrected net thrust, and corrected specific fuel consumption as functions of engine power setting. The acoustic results are divided into duct and far-field acoustic data. The NASA-designed core suppressor did the better job of suppressing aft end noise, but the splitter associated with it caused a significant engine performance penalty. The NASA core suppressor without the splitter suppressed most of the core noise without any engine performance penalty. (Author)

**A77-44453 \* #** Macroscopic study of time unsteady noise of an aircraft engine during static tests. B. J. Clark, M. F. Heidmann, and W. J. Kreim (NASA, Lewis Research Center, Cleveland, Ohio). *Acoustical Society of America, Meeting, 92nd, San Diego, Calif., Nov. 16-19, 1976, Paper, 14 p. 9 refs.*

Static tests of aircraft engines can exhibit greater than 10 dB random unsteadiness of tone noise levels because flow disturbances that prevail near test site facilities are ingested. Presumably such changes are related to installation and test site features. This paper presents some properties of unsteady noise observed at a NASA-Lewis facility during tests of a Lycoming YF-102 turbofan engine. Time and spatial variations in tone noise obtained from closely spaced far-field and inlet duct microphones are displayed. Long (0.5 sec) to extremely short (0.001 sec) intermittent tone bursts are observed. Unsteadiness of the tone, its harmonics, and the broadband noise show little similarity. In the far-field, identity of tone bursts is retained over a directivity angle of less than 10 deg. In the inlet duct, tone bursts appear to propagate axially but exhibit little circumferential similarity. They show only slight relationship to tone bursts observed in the far field. The results imply an intermittent generation of random mixtures of propagating duct modes. (Author)

**A77-44456 \* #** Simulation of flight-type engine fan noise in the NASA-Lewis 9 x 15 anechoic wind tunnel. M. F. Heidmann and D. A. Dietrich (NASA, Lewis Research Center, Cleveland, Ohio). *Acoustical Society of America, Meeting, 92nd, San Diego, Calif., Nov. 16-19, 1976, Paper, 24 p. 26 refs.*

A major problem in the measurement of aircraft engine fan noise is the difficulty of simulating, in a ground-based facility, the noise that occurs during flight. Flight-type noise as contrasted to the usual ground-static test noise exhibits substantial reductions in both (1) the time unsteadiness of tone noise and (2) the mean level of tones calculated to be nonpropagating or cut-off. A model fan designed with cut-off of the fundamental tone was acoustically tested in the anechoic wind tunnel under both static and tunnel flow conditions. The properties that characterize flight-type noise were progressively simulated with increasing tunnel flow. The distinctly lobed directivity pattern of propagating rotor/stator interaction modes was also observed. The results imply that the excess noise attributed to the ingestion of the flow disturbances that prevail near most static test facilities was substantially reduced with tunnel flow. The anechoic wind tunnel appears to be a useful facility for applied research on aircraft engine fan noise under conditions of simulated flight. (Author)

**A77-44457 \* #** Core noise source diagnostics on a turbofan engine using correlation and coherence techniques. A. Karchmer and M. Reshotko (NASA, Lewis Research Center, Cleveland, Ohio). *Acoustical Society of America, Meeting, 92nd, San Diego, Calif., Nov. 16-19, 1976, Paper, 27 p. 7 refs.*

Fluctuating pressure measurements at several locations within the core of a turbofan engine were made simultaneously with far-field acoustic measurements. Correlation and coherence techniques were used to determine the relative amplitude and phase relationships between core pressures at these various locations and between the core pressures and far-field acoustic pressure. The results indicate that the combustor is a low-frequency source region for acoustic propagation through the core nozzle and out to the far-field. Specifically, it was found that the relation between source pressure and the resulting sound pressure involves a 180 deg phase shift and an amplitude transfer function which varies approximately as frequency squared. This is shown to be consistent with a simplified model using fluctuating entropy as a source term. (Author)

**A77-44460 \* #** Effects of forward velocity on noise for a J85 turbojet engine with multitube suppressor from wind tunnel and flight tests. J. R. Stone, J. H. Miles, and N. B. Sargent (NASA, Lewis Research Center, Cleveland, Ohio). *Acoustical Society of America, Meeting, 92nd, San Diego, Calif., Nov. 16-19, 1976, Paper, 30 p. 28*

refs.

Flight tests and wind tunnel noise tests using a J85 engine with some representative jet exhaust noise suppressors are reported. Capabilities and limitations of the two types of experimental methods are evaluated with emphasis on investigation of forward velocity effects. The suppressor arrangement was a 104-elliptical-tube nozzle configuration, with or without an acoustically lined shroud. The suppressor noise levels are found not reduced as much by forward velocity as expected for unsuppressed jets. The directivity and forward velocity effects appear more similar to predicted trends for internally generated noise than for unsuppressed jet noise. R.D.V.

**A77-44462 \* #** Flight effects on exhaust noise for turbojet and turbofan engines - Comparison of experimental data with prediction. J. R. Stone (NASA, Lewis Research Center, Cleveland, Ohio). *Acoustical Society of America, Meeting, 92nd, San Diego, Calif., Nov. 16-19, 1976, Paper, 20 p. 23 refs.*

Recent experiments on the effects of flight on jet engine exhaust noise have produced apparently conflicting results. Some of these results do not agree with projections based on classical jet noise theories nor with experimental results from model jet simulated flight tests. It has been shown that in some of the cases reported, the proper corrections were not made to account for the distributed nature of the jet noise sources. It is shown herein that the remaining discrepancies can be reconciled by considering the combined effects of jet-mixing noise, internally-generated engine exhaust noise, and shock noise. This paper demonstrates that static and in-flight jet engine exhaust noise can be predicted with reasonable accuracy when the multiple-source nature of the problem is taken into account. Jet-mixing noise is predicted from an improved version of the NASA interim prediction method. Provisional methods of estimating internally-generated noise and shock noise flight effects are used, based partly on existing prediction methods and partly on recently reported engine data. (Author)

**A77-46520 \* #** Composite hubs for low cost turbine engines. C. C. Chamis (NASA, Lewis Research Center, Cleveland, Ohio). In: *Discover reinforced plastics; Proceedings of the Thirty-second Annual Conference, Washington, D.C., February 8-11, 1977. (A77-46505 22-24) New York, Society of the Plastics Industry, Inc., 1977, p. 15-C-1 to 15-C-7. 5 refs.*

A detailed stress analysis is performed using NASTRAN to demonstrate theoretically the adequacy of composite hubs for low cost turbine engine applications. The results show that composite hubs are adequate for this application from the steady state stress viewpoint. (Author)

**A77-51038 \* #** Measurement of far field combustion noise from a turbofan engine using coherence functions. A. M. Karchmer, M. Reshotko, and F. J. Montegani (NASA, Lewis Research Center, Cleveland, Ohio). *American Institute of Aeronautics and Astronautics, Aeracoustics Conference, 4th, Atlanta, Ga., Oct. 3-5, 1977, Paper 77-1277. 33 p. 14 refs.*

Coherence measurements between fluctuating pressure in the combustor of a YF-102 turbofan engine and far-field acoustic pressure were made. The results indicated that a coherent relationship between the combustor pressure and far-field existed only at frequencies below 250 Hz, with the peak occurring near 125 Hz. The coherence functions and the far-field spectra were used to compute the combustor-associated far-field noise in terms of spectra, directivity, and acoustic power, over a range of engine operating conditions. The acoustic results so measured were compared with results obtained by conventional methods, as well as with various semiempirical predictions schemes. Examination of the directivity patterns indicated a peak in the combustion noise near 120 deg (relative to the inlet axis). (Author)



**A77-51074 \*** # Summary of forward velocity effects on fan noise. C. E. Feiler and J. F. Groeneweg (NASA, Lewis Research Center, Cleveland, Ohio). *American Institute of Aeronautics and Astronautics, Aerodynamics Conference, 4th, Atlanta, Ga., Oct. 3-5, 1977, Paper 77-1319*, 11 p. 31 refs.

The available experimental data comparing the in-flight and static behavior of fan noise are reviewed. These results are then compared with recent data obtained for a fan stage tested with forward velocity in the NASA Lewis 9x15 low speed wind tunnel. Tentative conclusions are presented, based on the author's judgments, about the significance and nature of the changes in noise observed when a forward velocity is imposed. Finally, the implications of the emerging picture of in-flight fan source noise for suppressor design are discussed. (Author)

**A77-51087 \*** # Acoustic performance of inlet multiple-pure-tone suppressors installed on NASA Quiet Engine 'C'. H. E. Bloomer, J. W. Schaefer, E. J. Rice, and C. E. Feiler (NASA, Lewis Research Center, Cleveland, Ohio). *American Institute of Aeronautics and Astronautics, Aerodynamics Conference, 4th, Atlanta, Ga., Oct. 3-5, 1977, Paper 77-1333*, 10 p. 11 refs.

The purpose of the experimental program reported herein was to define the length of multiple pure tone (MPT) treatment required to reasonably suppress the MPT's produced by a supersonic tip speed fan and also determine what other suppression, broadband, and blade passing frequency (BPF), might be accomplished. The experimental results are presented in terms of both far-field and duct acoustic data. Front quadrant sound power level reduction in the far field is shown to agree with duct measurements over the range of treatment lengths. Detailed one-third octave and narrow band spectra at the maximum forward noise angle are presented. Some detailed analyses of one-third octave band amplitudes are shown as a function of far-field angle. An approximate spinning mode duct propagation analysis is then introduced which predicts the acoustic suppression by the treatment on the multiple pure tones. (Author)

**A77-51088 \*** # Effects of simulated flight on fan noise suppression. M. F. Heidmann and D. A. Dietrich (NASA, Lewis Research Center, Cleveland, Ohio). *American Institute of Aeronautics and Astronautics, Aerodynamics Conference, 4th, Atlanta, Ga., Oct. 3-5, 1977, Paper 77-1334*, 22 p. 17 refs.

Attenuation properties of three treated fan inlets were evaluated in the NASA-Lewis Anechoic Wind Tunnel using a subsonic tip speed, 50.8 cm-diameter fan. Tunnel flow simulated the inflow clean-up effect on source noise observed in flight and allowed observation of the blade passage frequency tone cut-off phenomenon. Acoustic data consisted of isolated inlet noise measured in the far field at two positions and with traverses at four frequencies. Averaged attenuation properties showed relative agreement of the inlets with their design intent; however, tunnel flow significantly affected the attenuation spectra. With no tunnel flow the strong blade passage tone was more highly attenuated than the adjacent broadband noise. With tunnel flow, when cut-off was observed, the attenuation at the tone frequency was comparable to that for broadband noise. Tunnel flow increased by several dB the maximum attenuation occurring at midfrequencies of the attenuation spectra. The combined effect of tunnel flow on attenuation and source noise resulted in suppressed fan noise levels throughout the spectra. Tunnel flow caused some substantial directivity variations that are interpreted as acoustic mode changes, with tunnel flow generally reducing the proportion of modes near cut-off. (Author)

**N77-10084 \*** # Pratt and Whitney Aircraft, East Hartford, Conn. **EXPERIMENTAL CLEAN COMBUSTOR PROGRAM: NOISE STUDY**

T. G. Sofrin and N. Ruloff, Jr. Sep. 1976 191 p refs (Contract NAS3-18544)

(NASA-CR-135108, PWA-5456) Avail. NTIS HC A09/MF A01 CSCL 21E

Under a Noise Addendum to the NASA Experimental Clean Combustor Program (ECCP) internal pressure fluctuations were measured during tests of JT9D combustor designs conducted in a burner test rig. Measurements were correlated with burner operating parameters using an expression relating farfield noise to these parameters. For a given combustor, variation of internal noise with operating parameters was reasonably well predicted by this expression but the levels were higher than farfield predictions and differed significantly among several combustors. For two burners, discharge stream temperature fluctuations were obtained with fast-response thermocouples to allow calculation of indirect combustion noise which would be generated by passage of the temperature inhomogeneities through the high pressure turbine stages of a JT9D turbofan engine. Using a previously developed analysis, the computed indirect combustion noise was significantly lower than total low frequency core noise observed on this and several other engines. Author

**N77-11046 \*** # AiResearch Mfg. Co., Phoenix, Ariz. **COMPRESSOR BLADE SETTING ANGLE ACCURACY STUDY, VOLUME 1 Final Report**

F. F. Holman and J. R. Kidwell Jun. 1976 107 p refs Sponsored by Army Air Mobility Res. and Develop. Lab., Moffett Field, Calif. 2 Vol.

(Contract NAS3-18024)

(NASA-CR-135068-Vol-1, AiResearch-73-311305-Vol-1) Avail. NTIS HC A06/MF A01 CSCL 21E

The aerodynamic test of a small, single stage, highly loaded, axial flow transonic compressor is covered. The stage was modified by fabricating a 24 blade rotor with mis-set blades in a repeating pattern - two degrees closed from nominal, two degrees open from nominal and nominal. The unit was instrumented to determine overall performance and average blade element data. High-response, dynamic pressure probes were installed to record pressure patterns at selected points in the flowpath. Testing was conducted at speeds from 70 to 94% of design equivalent speed with a conventional casing and also with circumferential grooves over the rotor tip. Testing indicated severe performance penalties were incurred as a result of the mis-set blading. Lower low, pressure ratio, and efficiency were observed for the stage with or without casing treatment. Periodic pressure variations were detected at every location where high response pressure sensors were located and were directly related to blading geometry. Author

**N77-11047 \*** # AiResearch Mfg. Co., Phoenix, Ariz. **COMPRESSOR BLADE SETTING ANGLE ACCURACY STUDY, VOLUME 2: DATA COMPILATION Final Report**

F. F. Holman and J. R. Kidwell Jun. 1976 133 p Sponsored by Army Air Mobility Res. and Develop. Lab., Moffett Field, Calif. 2 Vol.

(Contract NAS3-18024)

(NASA-CR-135068-Vol-2, AiResearch-73-311305-Vol-2) Avail. NTIS HC A07/MF A01 CSCL 21E

For abstract, see N77-11046

**N77-11048 \*** # AiResearch Mfg. Co., Phoenix, Ariz. **SMALL AXIAL COMPRESSOR TECHNOLOGY, VOLUME 1**

F. F. Holman, J. R. Kidwell, and T. C. Ware Jun. 1976 185 p refs Sponsored in part by Army

(Contract NAS3-17848)

(NASA-CR-134827-Vol-1, AiResearch-74-310862-Vol-1) Avail.

NTIS HC A05/MF A01 CSCL 21E

A scaled single-stage, highly-loaded, axial-flow transonic compressor was tested at speeds from 70 to 110% design equivalent speed to evaluate the effects of scaling compromises and the individual and combined effects of rotor tip running clearance and rotor shroud casing treatment on the overall and blade element performance. At design speed and 1% tip clearance the stage demonstrated an efficiency of 83.2% at 96.4% design flow and a pressure ratio of 1.865. Casing treatment increased design speed surge margin 2.0 points to 12.8%. Overall performance was essentially unchanged. An increase in rotor running clearance to 2.2% with smooth casing, reduced design



speed peak efficiency 5.7 points, flow by 7.4%, pressure ratio to 1.740, and surge margin to 5.4%. Reinstalling casing treatment regained 3.5 points in design speed peak efficiency, 4.7% flow, increased pressure ratio to 1.800 and surge margin to 8.7%.

Author

**N77-11049\*** AiResearch Mfg. Co., Phoenix, Ariz.  
**SMALL AXIAL COMPRESSOR TECHNOLOGY, VOLUME 2**  
**Final Report**

F. F. Holman, J. R. Kidwell, and T. C. Ware Jun. 1976 329 p  
Sponsored in part by Army  
(Contract NAS3-17846)  
(NASA-CR-134827-Vol-2; AiResearch-74-310862-Vol-2) Avail:  
NTIS HC A15/MF A01 CSCL 21E

Complete computer printout data are presented and supporting tests discussed in Volume 1.

Author

**N77-13069\*** Pratt and Whitney Aircraft, East Hartford, Conn.  
Commercial Products Div.  
**EXPERIMENTAL CLEAN COMBUSTOR PROGRAM,**  
**PHASE 2 Final Report**

R. Roberts, A. Peduzzi, and G. E. Vitti Nov. 1976 189 p refs  
(Contract NAS3-18544)  
(NASA-CR-134969; PWA-5418) Avail: NTIS  
HC A09/MF A01 CSCL 21E

Combustor pollution reduction technology for commercial CTOL engines was generated and this technology was demonstrated in a full-scale JT9D engine in 1976. Component rig refinement of the two best combustor concepts were tested. These concepts are the vorbix combustor, and a hybrid combustor which combines the pilot zone of the staged premix combustor and the main zone of the swirl-can combustor. Both concepts significantly reduced all pollutant emissions relative to the JT9D-7 engine combustor. However, neither concept met all program goals. The hybrid combustor met pollution goals for unburned hydrocarbons and carbon monoxide but did not achieve the oxides of nitrogen goal. This combustor had significant performance deficiencies. The Vorbix combustor met goals for unburned hydrocarbons and oxides of nitrogen but did not achieve the carbon monoxide goal. Performance of the vorbix combustor approached the engine requirements. On the basis of these results, the vorbix combustor was selected for the engine demonstration program. A control study was conducted to establish fuel control requirements imposed by the low-emission combustor concepts and to identify conceptual control system designs. Concurrent efforts were also completed on two addendums: an alternate fuels addendum and a combustion noise addendum.

Author

**N77-13060\*** Pratt and Whitney Aircraft, East Hartford, Conn.  
**STRESS ANALYSIS, THERMOMECHANICAL FATIGUE**  
**EVALUATION, AND ROOT SUBCOMPONENT TESTING OF**  
**GAMMA/GAMMA PRIME-DELTA EUTECTIC ALLOY Final**  
**Report**

K. D. Sheffler and J. J. Jackson Dec. 1976 93 p refs  
(Contract NAS3-19714; NAS3-19732)  
(NASA-CR-135005; PWA-5472) Avail: NTIS  
HC A05/MF A01 CSCL 21E

Thermomechanical fatigue (TMF) and root subcomponent tensile, creep, and low cycle fatigue (LCF) tests were conducted to determine the capability of a fully lamellar directionally solidified eutectic alloy to sustain the airfoil thermal fatigue and root attachment loads anticipated in advanced, hollow, high work turbine blades. A three dimensional finite element elastic stress analysis was performed on typical advanced hollow eutectic airfoil and root-platform designs to determine appropriate conditions for these tests. Results of TMF tests conducted on longitudinal specimens (stress axis parallel to the solidification direction) containing a simulated leading edge cooling hole pattern indicated the longitudinal TMF properties to be more than adequate for the particular advanced hollow blade analyzed, with the strain range for a 10,000 cycle life being more than 50% above the maximum strain range calculated for the advanced hollow blade.

Author

**N77-13063\*** General Electric Co., Cincinnati, Ohio.  
**FIBER COMPOSITE FAN BLADE IMPACT IMPROVEMENT**  
**PROGRAM Final Report**

T. L. Oller Dec. 1976 179 p refs  
(Contract NAS3-17836)  
(NASA-CR-135078; R76AEG461)  
HC A09/MF A01 CSCL 21E

Avail: NTIS

The results of a 20-month program, designed to investigate parameters which effect the foreign object damage resulting from ingestion of birds into fan blades are described. Work performed on this program included the design, fabrication, and impact testing of QCSEE fan blades to demonstrate improvement in resistance relative to existing blades and also the design and demonstration of a pin root attachment concept.

Author

**N77-14026\*** United Technologies Corp., East Hartford, Conn.  
**COST/BENEFIT ANALYSIS OF ADVANCED MATERIALS**  
**TECHNOLOGIES FOR FUTURE AIRCRAFT TURBINE**  
**ENGINES**

J. W. Bisset Nov. 1976 38 p refs  
(Contract NAS3-20072; et al)  
(NAS3-CR-135107; PWA-5453)  
HC A03/MF A01 CSCL 21E

Avail: NTIS

The cost/benefits of advance commercial gas turbine materials are described. Development costs, estimated payoffs and probabilities of success are discussed. The materials technologies investigated are: (1) single crystal turbine blades, (2) high strength hot isostatic pressed turbine disk, (3) advanced oxide dispersion strengthened burner liner, (4) bore entry cooled hot isostatic pressed turbine disk, (5) turbine blade tip - outer airseal system, and (6) advance turbine blade alloys.

M.C.F.

**N77-15038\*** Teledyne Continental Motors, Mobile, Ala. Aircraft Products Div.

**SCREENING ANALYSIS AND SELECTION OF EMISSION**  
**REDUCTION CONCEPTS FOR INTERMITTENT COMBUSTION**  
**AIRCRAFT ENGINES**

B. J. Rezy, J. E. Meyers, J. R. Tucker, and S. J. Stuckas Nov. 1976 202 p refs  
(Contract NAS3-19755)  
(NASA-CR-135074; TCM-5206)  
HC A10/MF A01 CSCL 21A

Avail: NTIS

An analysis was conducted to screen, evaluate, and select three engine exhaust emission reduction concepts from a group of 14 candidate alternatives. A comprehensive literature search was conducted to survey the emission reduction technology state-of-the-art and establish contact with firms working on intermittent combustion engine development and pollution reduction problems. Concept development, advantages, disadvantages, and expected emission reduction responses are stated. A set of cost effectiveness criteria was developed, appraised for relative importance, and traded off against each concept so that its merit could be determined. A decision model was used to aid the evaluators in managing the criteria, making consistent judgements, calculating merit scores, and ranking the concepts. An Improved Fuel Injection System, Improved Cooling Combustion Chamber, and a Variable Timing Ignition System were recommended to NASA for approval and further concept development. An alternate concept, Air Injection, was also recommended.

Author

**N77-15041\*** Pratt and Whitney Aircraft, East Hartford, Conn.  
Commercial Products Div.  
**ADVANCED SUPERSONIC PROPULSION STUDY,**  
**PHASE 3 Final Report**

R. A. Howlett, J. Johnson, J. Sabatella, and T. Sewall Dec. 1976 158 p refs  
(Contract NAS3-19540)  
(NASA-CR-135148; PWA 5461)  
HC A08/MF A01 CSCL 21E

Avail: NTIS

The variable stream control engine is determined to be the most promising propulsion system concept for advanced supersonic cruise aircraft. This concept uses variable geometry components and a unique throttle schedule for independent control

of two flow streams to provide low jet noise at takeoff and high performance at both subsonic and supersonic cruise. The advanced technology offers a 25% improvement in airplane range and an 8 decible reduction in takeoff noise, relative to first generation supersonic turbojet engines. Author

**N77-15043\*** General Electric Co., Cincinnati, Ohio. Aircraft Engine Group.

**STUDY OF UNCONVENTIONAL AIRCRAFT ENGINES DESIGNED FOR LOW ENERGY CONSUMPTION**

R. E. Neitzel, R. Hirschhorn, and R. P. Johnston Dec. 1976 165 p refs

(Contract NAS3-19519)

(NASA-CR-135136; R76AEG597)

Avail: NTIS

HC A08/MF A01 CSCL 21E

A study of unconventional engine cycle concepts, which may offer significantly lower energy consumption than conventional subsonic transport turbofans, is described herein. A number of unconventional engine concepts were identified and parametrically studied to determine their relative fuel-saving potential. Based on results from these studies, regenerative, geared, and variable-boost turbofans, and combinations thereof, were selected along with advanced turboprop cycles for further evaluation and refinement. Preliminary aerodynamic and mechanical designs of these unconventional engine configurations were conducted and mission performance was compared to a conventional, direct-drive turbofan reference engine. Consideration is given to the unconventional concepts, and their state of readiness for application. Areas of needed technology advancement are identified. Author

**N77-15044\*** Pratt and Whitney Aircraft, East Hartford, Conn. **ANALYSIS AND DESIGN OF DIGITAL OUTPUT INTERFACE DEVICES FOR GAS TURBINE ELECTRONIC CONTROLS** Final Report

D. M. Newirth and E. W. Koenig Dec. 1976 66 p

(Contract NAS3-19898)

(NASA-CR-135135; PWA-5471)

Avail: NTIS

HC A04/MF A01 CSCL 21E

A trade study was performed on twenty-one digital output interface schemes for gas turbine electronic controls to select the most promising scheme based on criteria of reliability, performance, cost, and sampling requirements. The most promising scheme, a digital effector with optical feedback of the fuel metering valve position, was designed. Author

**N77-15082\*** Solar, San Diego, Calif. **ADVANCED RADIAL INFLOW TURBINE ROTOR PROGRAM: DESIGN AND DYNAMIC TESTING** Final Report, 10 Jun. 1974 - 1 Jun. 1976

Colin Rodgers Sep. 1976 91 p ref

(Contract NAS3-18524)

(NASA-CR-135080; SOLAR-ER-2519)

Avail: NTIS

HC A05/MF A01 CSCL 21E

The advancement of small, cooled, radial inflow turbine technology in the area of operation at higher turbine inlet temperature is discussed. The first step was accomplished by designing, fabricating, and subjecting to limited mechanical testing an advanced gas generator rotating assembly comprising a radial inflow turbine and two-stage centrifugal compressor. The radial inflow turbine and second stage compressor were designed as an integrally machined monorotor with turbine cooling taking place basically by conduction to the compressor. Design turbine inlet rotor gas temperature, rotational speed, and overall gas generator compressor pressure ratio were 1422 K (2560 R), 71,222 rpm, and 10/1 respectively. Mechanical testing on a fabricated rotating assembly and bearing system covered 1,000 cold start/stop cycles and three spins to 120 percent design speed (85,466 rpm). Author

**N77-17060\*** General Electric Co., Cincinnati, Ohio. Dept. of Advanced Engineering and Technology Programs.

**SINGLE-STAGE, LOW-NOISE, ADVANCED TECHNOLOGY FAN. VOLUME 4: FAN AERODYNAMICS. SECTION 1: RESULTS AND ANALYSIS**

T. J. Sullivan, I. Silverman, and D. R. Little Feb. 1977 156 p refs

(Contract NAS3-16813)

(NASA-CR-134892; Doc-R76AEG585-Vol-4) Avail: NTIS HC A08/MF A01 CSCL 20A

Test results at design speed show fan total pressure ratio, weight flow, and adiabatic efficiency to be 2.2, 2.9, and 1.8% lower than design goal values. The hybrid acoustic inlet (which utilizes a high throat Mach number and acoustic wall treatment for noise suppression) demonstrated total pressure recoveries of 98.9% and 98.2% at takeoff and approach. Exhaust duct pressure losses differed between the hardwall duct and treated duct with splitter by about 0.6% to 2.0% in terms of fan exit average total pressure (depending on operating condition). When the measured results were used to estimate pressure losses, a cruise sfc penalty of 0.68%, due to the acoustically treated duct, was projected. Author

**N77-17061\*** General Electric Co., Cincinnati, Ohio. Dept. of Advanced Engineering and Technology Programs.

**SINGLE STAGE, LOW NOISE, ADVANCED TECHNOLOGY FAN. VOLUME 4: FAN AERODYNAMICS. SECTION 2: OVERALL AND BLADE ELEMENT PERFORMANCE DATA TABULATIONS**

T. J. Sullivan Feb. 1977 340 p refs

(Contract NAS3-16813)

(NASA-CR-134893; Doc-R76AEG586-Vol-4) Avail: NTIS HC A15/MF A01 CSCL 20A

For abstract, see N77-17060

**N77-17092\*** Teledyne Continental Motors, Mobile, Ala. **TCM AIRCRAFT PISTON ENGINE EMISSION REDUCTION PROGRAM**

Bernard Rezy In NASA. Lewis Res. Center Aircraft Piston Eng. Exhaust Emissions Symp. Sep. 1976 p 227-254 (For primary document see N77-17081 08-07)

(Contract NAS3-19755)

Avail: NTIS HC A16/MF A01 CSCL 21E

The technology necessary to safely reduce general aviation piston engine exhaust emissions to meet the EPA 1980 Emission Standards with minimum adverse effects on cost, weight, fuel economy, and performance was demonstrated. A screening and assessment of promising emission reduction concepts was provided, and the preliminary design and development of those concepts was established. A system analysis study and a decision making procedure were used by TCM to evaluate, trade off, and rank the candidate concepts from a list of 14 alternatives. Cost, emissions, and 13 other design criteria considerations were defined and traded off against each candidate concept to establish its merit and emission reduction usefulness. A computer program was used to aid the evaluators in making the final choice of three concepts. Author

**N77-17100\*** Teledyne Continental Motors, Mobile, Ala. **REVIEW OF MEASUREMENT AND TESTING PROBLEMS**

In NASA. Lewis Res. Center Aircraft Piston Eng. Exhaust Emissions Symp. Sep. 1976 p 357-378 (For primary document see N77-17081 08-07)

Avail: NTIS HC A16/MF A01 CSCL 21E

The exhaust emission test was designed to measure hydrocarbons, carbon monoxide, and oxides of nitrogen concentrations and determine mass emissions through calculations during a simulated aircraft landing-takeoff cycle. The calculations required to convert exhaust emission concentrations (raw emission measurements) into mass emissions were emphasized. Author

**N77-18158\*** Rockwell International Corp., Los Angeles, Calif.  
**METHODS FOR COMPARATIVE EVALUATION OF PROPULSION SYSTEM DESIGNS FOR SUPERSONIC AIRCRAFT**  
 R. M. Tyson, R. Y. Mairs, F. D. Halferty, Jr., B. E. Moero, D. Chaloff, and A. W. Knudsen Jun. 1976 181 p refs  
 (Contract NAS3-19858)

(NASA-CR-135110; NA-70-470)  
 HC A09/MF A01 CSCL 21E

Avail: NTIS

The propulsion system comparative evaluation study was conducted to define a rapid, approximate method for evaluating the effects of propulsion system changes for an advanced supersonic cruise airplane, and to verify the approximate method by comparing its mission performance results with those from a more detailed analysis. A table look up computer program was developed to determine nacelle drag increments for a range of parametric nacelle shapes and sizes. Aircraft sensitivities to propulsion parameters were defined. Nacelle shapes, installed weights, and installed performance was determined for four study engines selected from the NASA supersonic cruise aircraft research (SCAR) engine studies program. Both rapid evaluation method (using sensitivities) and traditional preliminary design methods were then used to assess the four engines. The method was found to compare well with the more detailed analyses. Author

**N77-20102\*** Pratt and Whitney Aircraft, East Hartford, Conn. Commercial Products Div.

**ANALYTICAL SCREENING OF LOW EMISSIONS, HIGH PERFORMANCE DUCT BURNERS FOR SUPERSONIC CRUISE AIRCRAFT ENGINES Final Report**  
 R. A. Lohmann and G. T. Riecke Mar. 1977 97 p refs  
 (Contract NAS3-19781)

(NASA-CR-135157; PWA-5489)  
 HC A05/MF A01 CSCL 21E

Avail: NTIS

An analytical screening study was conducted to identify duct burner concepts capable of providing low emissions and high performance in advanced supersonic engines. Duct burner configurations ranging from current augmentor technology to advanced concepts such as premix-prevaporized burners were defined. Aerochemical and mechanical design studies provided the basis for screening these configurations using the criteria of emissions, performance, engine compatibility, cost, weight and relative risk. Technology levels derived from recently defined experimental low emissions main burners are required to achieve both low emissions and high performance goals. A configuration based on the Vorbix (Vortex burning and mixing) combustor concept was analytically determined to meet the performance goals and is consistent with the fan duct envelope of a variable cycle engine. The duct burner configuration has a moderate risk level compatible with the schedule of anticipated experimental programs. Author

**N77-18070\*** Detroit Diesel Allison, Indianapolis, Ind.  
**DETAILED DESIGN OF A QUIET HIGH FLOW FAN**

J. D. Soltau, M. J. Orslup, A. A. Beguhn, F. M. Wiles, and M. J. Anderson Feb. 1977 229 p refs  
 (Contract NAS3-19433)

(NASA-CR-135126; EDR-9071)

Avail: NTIS

HC A11/MF A01 CSCL 21E

A single stage fan was designed to demonstrate the noise abatement properties of near-sonic inlet flow and long-chord stator vanes for the reduction of both upstream and downstream propagated fan source noise. It is designed to produce a pressure ratio of 1.653:1 with an adiabatic efficiency of 83.9%. The fan has a 508 mm inlet diameter with a hub/tip ratio of 0.426 and a design tip speed of 533.4 m/sec. The design inlet specific flow rate is 219.71 kg/sec sq m and there are 10 tandem stator vanes with a combined aspect ratio of 0.54. Author

**N77-20101\*** Pratt and Whitney Aircraft, East Hartford, Conn.  
**ULTRA HIGH TIP SPEED (670.6 m/sec) FAN STAGE WITH COMPOSITE ROTOR: AERODYNAMIC AND MECHANICAL DESIGN**

J. E. Halle, G. D. Burger, and R. E. Dundas Mar. 1977 198 p refs  
 (Contract NAS3-15335)

(NASA-CR-135122; PWA-5487)

Avail: NTIS

HC A09/MF A01 CSCL 21E

A highly loaded, single-stage compressor having a tip speed of 670.6 m/sec was designed for the purpose of investigating very high tip speeds and high aerodynamic loadings to obtain high stage pressure ratios at acceptable levels of efficiency. The design pressure ratio is 2.8 at an adiabatic efficiency of 84.4%. Corrected design flow is 83.4 kg/sec; corrected design speed is 15,200 rpm; and rotor inlet tip diameter is 0.853 m. The rotor uses multiple-circular-arc airfoils from 0 to 15% span, precompression airfoils assuming single, strong oblique shocks from 21 to 43% span, and precompression airfoils assuming multiple oblique shocks from 52% span to the tip. Because of the high tip speeds, the rotor blades are designed to be fabricated of composite materials. Two composite materials were investigated: Courtaulds HTS graphite fiber in a Kevlar 601 polyimide matrix and the same fibers in a PMR polyimide matrix. In addition to providing a description of the aerodynamic and mechanical design of the

670.0 m/sec fan, discussion is presented of the results of structural tests of blades fabricated with both types of matrices. Author

**N77-20103\*** Computer Systems International, Inc., Seabrook, Md.

**A STUDY OF THE OPTIMIZATION METHOD USED IN THE NAVY/NASA GAS TURBINE ENGINE COMPUTER CODE Final Report**

Jerry L. Horswood and Samuel Pines (Anal. Mech. Assoc., Inc., Jericho, N. Y.) Jan. 1977 63 p refs  
 (Contract NAS3-20280)

(NASA-CR-135180; AMA-77-1)

Avail: NTIS

HC A04/MF A01 CSCL 21E

Sources of numerical noise affecting the convergence properties of the Powell's Principal Axis Method of Optimization in the NAVY/NASA gas turbine engine computer code were investigated. The principal noise source discovered resulted from loose input tolerances used in terminating iterations performed in subroutine CALCFX to satisfy specified control functions. A minor source of noise was found to be introduced by an insufficient number of digits in stored coefficients used by subroutine THERM in polynomial expressions of thermodynamic properties. Tabular results of several computer runs are presented to show the effects on program performance of selective corrective actions taken to reduce noise. Author

**N77-20105\*** General Electric Co., Cincinnati, Ohio. Aircraft Engine Group.

**PRELIMINARY DESIGN STUDY OF ADVANCED MULTI-STAGE AXIAL FLOW CORE COMPRESSORS Final Report, May 1976 - Jan. 1976**

D. C. Wisler, C. C. Koch, and L. H. Smith, Jr. Feb. 1977 95 p refs  
 (Contract NAS3-19444)

(NASA-CR-135133; R77AEG222)

Avail: NTIS

HC A05/MF A01 CSCL 21E

A preliminary design study was conducted to identify an advanced core compressor for use in new high-bypass-ratio turbofan engines to be introduced into commercial service in the 1980's. An evaluation of anticipated compressor and related component 1985 state-of-the-art technology was conducted. A parametric screening study covering a large number of compressor designs was conducted to determine the influence of the major compressor design features on efficiency, weight, cost, blade life, aircraft direct operating cost, and fuel usage. The trends observed in the parametric screening study were used to develop three high-efficiency, high economic-payoff compressor designs. These three compressors were studied in greater detail to better evaluate their aerodynamic and mechanical feasibility. Author

**N77-20110\*** Detroit Diesel Allison, Indianapolis, Ind.  
**DEFINITION OF PROPULSION SYSTEM FOR V/STOL**  
**RESEARCH AND TECHNOLOGY AIRCRAFT Final Report**  
 Jan. 1977 105 p  
 (Contract NAS3-20034) EDR-9020 Avail: NTIS  
 (NASA-CR-135161) HC A06/MF A01 CSCL 21E

Wind tunnel test support, aircraft contractor support, a propulsion system computer card deck, preliminary design studies, and propulsion system development plan are reported. The Propulsion system consists of two lift/cruise turbofan engines, one turboshaft engine and one lift fan connected together with shafting into a combiner gearbox. Distortion parameter levels from 40 x 80 test data were within the established XT701-AD-700 limits. The three engine-three fan system card deck calculates either vertical or conventional flight performance, installed or uninstalled. Design study results for XT701 engine modifications, bevel gear cross shaft location, fixed and tilt fan frames and propulsion system controls are described. Optional water-alcohol injection increased total net thrust 10.3% on a 90 F day. Engines have sufficient turbine life for 500 hours of the RTA duty cycle. Author

**N77-20113\*** General Electric Co., Evendale, Ohio. Dept. of Advanced Engineering and Technology Programs.  
**SINGLE STAGE, LOW NOISE, ADVANCED TECHNOLOGY FAN. VOLUME 5: FAN ACOUSTICS. SECTION 2: ONE-THIRD OCTAVE DATA TABULATIONS AND SELECTED NARROWBAND TRACES Final Report**  
 R. R. Jutras May 1976 479 p refs 5 Vol.  
 (Contract NAS3-16813) R75AEG431 Avail: NTIS  
 (NASA-CR-134895) HC A21/MF A01 CSCL 21E

The raw-acoustic data corrected to standard day, from acoustic tests performed on a 0.508-scale fan vehicle of a 111,300 newton thrust, full-size engine, which has application on an advanced transport aircraft, are presented. The single-stage advanced technology fan was designed to a pressure ratio of 1.8 at a tip speed of 503 m/sec to achieve the desired pressure ratio in a single-stage fan with low radius ratio, and to maintain adequate stall margin. The two basic approaches taken in the acoustic design were: (1) minimization of noise at the source, and (2) suppression of the generated noise in the inlet and bypass exhaust duct. Suppression of the generated noise was accomplished in the inlet through use of the hybrid concept (wall acoustic treatment plus airflow acceleration suppression) and in the exhaust duct with extensive acoustic treatment including a splitter. The goal of the design was attainment of twenty effective perceived noise decibels. The suppression goal of FAR 36-20 was not reached, but improvements in the technology of both front and aft fan-noise suppression were realized. Author

**N77-21069\*** General Electric Co., Cincinnati, Ohio. Aircraft Engine Group.  
**LINEARIZED BLADE ROW COMPRESSION COMPONENT MODEL. STABILITY AND FREQUENCY RESPONSE ANALYSIS OF A J85-3 COMPRESSOR**  
 W. A. Tesch, R. H. Muszko, and W. G. Steenken Sep. 1976 88 p refs  
 (Contract NAS3-19854) R76AEG454 Avail: NTIS  
 (NASA-CR-135162) HC A05/MF A01 CSCL 21E

NASA developed stability and frequency response analysis techniques were applied to a dynamic blade row compression component stability model to provide a more economic approach to surge line and frequency response determination than that provided by time-dependent methods. This blade row model was linearized and the Jacobian matrix was formed. The clean-inlet-flow stability characteristics of the compressors of two J85-13 engines were predicted by applying the alternate Routh-Hurwitz stability criterion to the Jacobian matrix. The predicted surge line agreed with the clean-inlet-flow surge line predicted by the time-dependent method to a high degree except for one engine at 94% corrected speed. No satisfactory explanation of this discrepancy was found. The frequency response of the linearized system was determined by evaluating its Laplace transfer function

The results of the linearized-frequency-response analysis agree with the time-dependent results when the time-dependent inlet total-pressure and exit-flow function amplitude boundary conditions are less than 1 percent and 3 percent, respectively. The stability analysis technique was extended to a two-sector parallel compressor model with and without interstage crossflow and predictions were carried out for total-pressure distortion extents of 180 deg, 90 deg, 60 deg, and 30 deg. Author

**N77-23108\*** Hamilton Standard, Windsor Locks, Conn.  
**VARIABLE PITCH FAN SYSTEM FOR NASA/NAVY RESEARCH AND TECHNOLOGY AIRCRAFT**  
 W. P. Ryan, D. M. Black, and A. F. Yates Apr. 1977 29 p  
 (Contract NAS3-20033) Avail: NTIS HC A03/MF A01 CSCL 21E

Preliminary design of a shaft driven, variable-pitch lift fan and lift-cruise fan was conducted for a V/STOL Research and Technology Aircraft. The lift fan and lift-cruise fan employed a common rotor of 157.5 cm diameter, 1.18 pressure ratio variable-pitch fan designed to operate at a rotor-tip speed of 284 mps. Fan performance maps were prepared and detailed aerodynamic characteristics were established. Cost/weight/risk trade studies were conducted for the blade and fan case. Structural sizing was conducted for major components and weights determined for both the lift and lift-cruise fans. Author

**N77-25171\*** Boeing Co., Seattle, Wash.  
**A METHOD TO ESTIMATE WEIGHT AND DIMENSIONS OF AIRCRAFT GAS TURBINE ENGINES. VOLUME 1: METHOD OF ANALYSIS Final Report**  
 R. J. Pera, E. Onat, G. W. Klees, and E. Tjonneland May 1977 50 p refs  
 (Contract NAS3-19913) D6-44258-Vol-1 Avail: NTIS  
 (NASA-CR-135170) HC A03/MF A01 CSCL 21E

Weight and envelope dimensions of aircraft gas turbine engines are estimated within plus or minus 5% to 10% using a computer method based on correlations of component weight and design features of 29 data base engines. Rotating components are estimated by a preliminary design procedure where blade geometry, operating conditions, material properties, shaft speed, hub-tip ratio, etc., are the primary independent variables used. The development and justification of the method selected, the various methods of analysis, the use of the program, and a description of the input/output data are discussed. Author

**N77-25172\*** Boeing Co., Seattle, Wash.  
**A METHOD TO ESTIMATE WEIGHT AND DIMENSIONS OF AIRCRAFT GAS TURBINE ENGINES. VOLUME 2: USER'S MANUAL Final Report**  
 R. J. Pera, E. Onat, G. W. Klees, and E. Tjonneland May 1977 42 p refs  
 (Contract NAS3-19913) D6-44258-Vol-2 Avail: NTIS  
 (NASA-CR-135171) HC A03/MF A01 CSCL 21E  
 For abstract, see N77-25171.

**N77-25173\*** Boeing Co., Seattle, Wash.  
**A METHOD TO ESTIMATE WEIGHT AND DIMENSIONS OF AIRCRAFT GAS TURBINE ENGINES. VOLUME 3: PROGRAMMER'S MANUAL Final Report**  
 R. J. Pera, E. Onat, N. L. Prewitt, G. W. Klees, and E. Tjonneland May 1977 167 p  
 (Contract NAS3-19913) D6-44258-Vol-3 Avail: NTIS  
 (NASA-CR-135172) HC A08/MF A01 CSCL 21E  
 For abstract, see N77-25171.

**N77-28134\*** Curtiss-Wright Corp., Wood-Ridge, N.J.  
**PERFORMANCE, EMISSIONS, AND PHYSICAL CHARACTERISTICS OF A ROTATING COMBUSTION AIRCRAFT ENGINE**

M. Berkowitz, W. L. Hermes, R. E. Mount, and D. Myers Dec. 1976 118 p refs

(Contract NAS3-20030)

(NASA-CR-135119; CW-WR-76-028.2) Avail: NTIS HC A06/MF A01 CSCL 21A

The RC2-75, a liquid cooled two chamber rotary combustion engine (Wankel type), designed for aircraft use, was tested and representative baseline (212 kW, 285 BHP) performance and emissions characteristics established. The testing included running fuel/air mixture control curves and varied ignition timing to permit selection of desirable and practical settings for running wide open throttle curves, propeller load curves, variable manifold pressure curves covering cruise conditions, and EPA cycle operating points. Performance and emissions data were recorded for all of the points run. In addition to the test data, information required to characterize the engine and evaluate its performance in aircraft use is provided over a range from one half to twice its present power. The exhaust emissions results are compared to the 1980 EPA requirements. Standard day take-off brake specific fuel consumption is 356 g/KW-HR (585 lb/BHP-HR) for the configuration tested.

Author

**N77-28135\*** General Electric Co., Cincinnati, Ohio. Aircraft Engine Group.

**BORON/ALUMINUM FAN BLADES FOR SCAR ENGINES Final Report**

R. G. Stabrylla and R. G. Carlson Jun. 1977 129 p ref (Contract NAS3-18910)

(NASA-CR-135184) Avail: NTIS HC A07/MF A01 CSCL 21E

Processing procedures were developed to enhance boron/aluminum bond behavior and foreign object damage (FOD) tolerance. Design and analysis indicated that the J101 Stage 1 fan blade meets the required frequencies without a midspan shroud. The fabricability of full size J101 blades was assessed, while six blades were fabricated and finished machined. Author

**N77-27115\*** + Detroit Diesel Allison, Indianapolis, Ind.  
**PRELIMINARY DESIGN OF PROPULSION SYSTEM FOR V/STOL RESEARCH AND TECHNOLOGY AIRCRAFT Final Report**

Mar. 1977 215 p

(Contract NAS3-20053)

(NASA-CR-135207; DDA-EDR-9082) Avail: NTIS HC A01 CSCL 21E

The V/STOL Research and Technology Aircraft (RTA) propulsion system design effort is limited to components of the lift/cruise engines, turboshaft engine modifications, lift fan assembly, and propulsion system performance generation. The uninstalled total net thrust with all engines and fans operating at intermediate power was 37,114 pounds. Uninstalled system total net thrust was 27,102 pounds when one lift/cruise is inoperative. Components have lives above the 500 hours of the RTA duty cycle. The L/C engine used in a fixed nacelle has the cross shaft forward of the reduction gear whereas the cross shaft is aft of the reduction gear in a tilt nacelle L/C engine. The lift/cruise gearbox contains components and technologies from other DDA engines. The rotor has a 62-inch diameter and contains 22 composite blades that have a hub/tip ratio of 0.454. The blade pitch change mechanism contains hydraulic and mechanical redundancy. The lift fan assembly is completely self-contained including oil cooling in 10 exit vanes. Author

**N77-27118\*** Georgia Inst. of Tech., Atlanta. School of Aerospace Engineering.

**AN INVESTIGATION OF COMBUSTION AND ENTROPY NOISE Final Report, 15 Jul. 1974 - 14 Jul. 1977**

W. C. Strahle 15 Jul. 1977 97 p refs

(Grant NSG-3015)

(NASA-CR-135220) Avail: NTIS HC A05/MF A01 CSCL

21E

The relative importance of entropy and direct combustion noise in turbopropulsion systems and the parameters upon which these noise sources depend were studied. Theory and experiment were employed to determine that at least with the apparatus used here, entropy noise can dominate combustion noise if there is a sufficient pressure gradient terminating the combustor. Measurements included combustor interior fluctuating pressure, near and far field fluctuating pressure, and combustor exit plane fluctuating temperatures, as well as mean pressures and temperatures. Analysis techniques included spectral, cross-correlation, cross power spectra, and ordinary and partial coherence analysis. Also conducted were combustor liner modification experiments to investigate the origin of the frequency content of combustion noise. Techniques were developed to extract nonpropagational pseudo-sound and the heat release fluctuation spectra from the data.

Author

**N77-28122\*** General Electric Co., Evendale, Ohio. Aircraft Engine Group.

**ATTENUATION OF UPSTREAM-GENERATED LOW FREQUENCY NOISE BY GAS TURBINES Final Report**

V. L. Doyle and R. K. Matta Aug. 1977 232 p refs

(Contract NAS3-19435)

(NASA-CR-135219, R77AEG482)

Avail: NTIS

HC A11/MF A01 CSCL 20A

The acoustic transfer functions of low frequency (below 3500 Hz) noise through aircraft turbines were investigated. Model test results were compared with theoretical predictions in order to assess the validity of the theory. Component tests were conducted on both high pressure and low pressure model turbines. The influence of inlet temperature and turbine speed attenuation was evaluated, while the effects of turbine pressure ratio, blade-row choking, and additional downstream stages were determined.

Preliminary identification of pertinent aeroacoustic correlating parameters was made.

Author

**N77-28160\*** General Electric Co., Cincinnati, Ohio. Aircraft Engine Group.

**IMPROVED HIGH PRESSURE TURBINE SHROUD Final Report, 26 Jun. 1974 - 24 Jan. 1977**

I. I. Bessen, D. V. Rigney, and R. C. Schwab Feb. 1977 82 p (Contract NAS3-18905)

(NASA-CR-135181, R77AEG481)

Avail: NTIS

HC A05/MF A01 CSCL 21E

A new high pressure turbine shroud material has been developed from the consolidation of prealloyed powders of Ni, Cr, Al and Y. The new material, a filler for cast turbine shroud body segments, is called Genaseal. The development followed the identification of oxidation resistance as the primary cause of prior shroud deterioration, since conversion to oxides reduces erosion resistance and increases spalling under thermal cycled engine conditions. The NiCrAlY composition was selected in preference to NIAL and FeCrAlY alloys, and was formulated to a prescribed density range that offers suitable erosion resistance, thermal conductivity and elastic modulus for improved behavior as a shroud.

Author

**N77-30119\*** Naval Air Propulsion Test Center, Trenton, N.J.  
**ROTOR BURST PROTECTION PROGRAM: EXPERIMENTATION TO PROVIDE GUIDELINES FOR THE DESIGN OF TURBINE ROTOR BURST FRAGMENT CONTAINMENT RINGS Final Report, 1 1972 - 1978**

G. J. Mangano, J. T. Salvino, and R. A. DeLucia Mar. 1977 53 p refs

(NASA-CR-135166; NAPT-PE-98)

Avail: NTIS

HC A04/MF A01 CSCL 21E

The results of a program of rotor burst containment experimentation that provides guidelines for the design of optimum weight turbine rotor disk fragment containment rings are presented. The guidelines were derived by establishing the relationships between a measure of the ring's capability to contain fragment energy with respect to its weight and other significant

ing and rotor variables such as the: (1) rotor tip diameter; (2) number of rotor fragments; and (3) ring radial thickness and axial length. The experiments consisted mainly of bursting 14 and 31 inch diameter turbine rotors into encircling containment rings made from centrifugally cast 4130 steel. Rules are given for achieving optimum weight ring designs. Author

**N77-31148\*** General Electric Co., Cincinnati, Ohio. Advanced Engineering and Technology Programs Dept.  
**NASA/NAVY LIFT/CRUISE FAN. PHASE 1: DESIGN SUMMARY**

Sep. 1977 276 p refs

(Contract NAS3-20046)

(NASA-CR-135242; R77AEG180)

Avail: NTIS

HC A11/MF A01 CSCL 21E

The initial design of the LCF459 lift/cruise fan system is documented. The LCF459 is a 1.5 meter diameter turbojet lift/cruise fan whose design point pressure ratio is 1.32 at a tip speed of 353 meters per second. The gas source for the tip turbine is the YJ97-GE-100 engine. Author

**N77-32161\*** Pratt and Whitney Aircraft, East Hartford, Conn. Commercial Products Div.

**EXPERIMENTAL CLEAN COMBUSTOR PROGRAM.**

**PHASE 3 Final Report**

R. Roberts, A. Fiorentino, and W. Greene. Oct. 1977 123 p refs

(Contract NAS3-19447)

(NASA-CR-135253; PWA-5493)

Avail: NTIS

HC A06/MF A01 CSCL 21E

A two-stage vortex burning and mixing combustor and associated fuel system components were successfully tested at steady state and transient operating conditions. The combustor exceeded the program goals for all three emissions species, with oxides of nitrogen 10 percent below the goal, carbon monoxide 26 percent below the goal, and total unburned hydrocarbons 75 percent below the goal. Relative to the JT9D-7 combustor, the oxides of nitrogen were reduced by 58 percent, carbon monoxide emissions were reduced by 69 percent, and total unburned hydrocarbons were reduced by 9 percent. The combustor efficiency and exit temperature profiles were comparable to those of production combustor. Acceleration and starting characteristics were deficient relative to the production engine. Author

**N77-33166\*** AiResearch Mfg. Co., Phoenix, Ariz.  
**POLLUTION REDUCTION TECHNOLOGY PROGRAM FOR SMALL JET AIRCRAFT ENGINES. PHASE 1 Final Report.**  
Nov. 1974 - Jun. 1976

T. W. Bruce, F. G. Davis, T. E. Kuhn, and H. C. Mongie. Sep. 1977 177 p refs

(Contract NAS3-18560)

(NASA-CR-135214; AiResearch-21-2498)

Avail: NTIS

HC A08/MF A01 CSCL 21E

A series of combustor pressure rig screening tests was conducted on three combustor concepts applied to the TFE731-2 turbofan engine combustion system for the purpose of evaluating their relative emissions reduction potential consistent with prescribed performance, durability, and envelope constraints. The three concepts and their modifications represented increasing potential for reducing emission levels with the penalty of increased hardware complexity and operational risk. Concept 1 entailed advanced modifications to the present production TFE731-2 combustion system. Concept 2 was based on the incorporation of an axial air-assisted airblast fuel injection system. Concept 3 was a staged premix/prevaporizing combustion system. Significant emissions reductions were achieved in all three concepts, consistent with acceptable combustion system performance. Concepts 2 and 3 were identified as having the greatest achievable emissions reduction potential, and were selected to undergo refinement to prepare for ultimate incorporation within an engine. Author

**A77-22215 \*** Jet noise source modification due to forward flight. R. S. Larson, C. J. McColgan, and A. B. Packman (United Technologies Corp., Pratt and Whitney Aircraft Group, East Hartford, Conn.). *American Institute of Aeronautics and Astronautics, Aerospace Sciences Meeting, 15th, Los Angeles, Calif., Jan. 24-26, 1977, Paper 77-58.* 9 p. 13 refs. Contract No. NAS3-17866.

The effects of forward flight on the turbulence characteristics of a jet in a co-flowing stream have been determined for a 2.22 inch circular jet in a 36 inch free jet wind tunnel. The nozzle exit velocity was 400 ft/sec, and the tunnel velocity was set at 0, 40, 120 and 200 ft/sec. Measurements of flow properties including mean velocity, turbulence intensity and spectra, convection velocity, integral length scale, and convected integral time scale were carried out using two linearized hot wires. Results were used to predict changes due to flight in the jet acoustic sources. The noise reductions for a cold jet with a velocity of 1000 ft/sec, due to the change in acoustic sources in flight, agreed well at all angles with measured noise reductions. Author

**A77-26461 \*** Evaluation of a staged fuel combustor for turboprop engines. A. J. Verdouw (General Motors Corp., Detroit Diesel Allison Div., Indianapolis, Ind.). *American Society of Mechanical Engineers, Winter Annual Meeting, New York, N.Y., Dec. 5-10, 1976, Paper 76-WA/GT-5.* 13 p. 5 refs. Members, \$1.50; nonmembers, \$3.00. Contract No. NAS3-186561.

Proposed EPA emission regulations require emission reduction by 1979 for various gas turbine engine classes. Extensive combustion technology advancements are required to meet the proposed regulations. The T56 turboprop engine requires CO, UHC, and smoke reduction. A staged fuel combustor design was tested on a combustion rig to evaluate emission reduction potential in turboprop engines from fuel zoning. The can-type combustor has separately fueled-pilot and main combustion zones in series. The main zone fueling system was arranged for potential incorporation into the T56 with minor or no modifications to the basic engine. Three combustor variable geometry systems were incorporated to evaluate various airflow distributions. Emission results with fixed geometry operation met all proposed EPA regulations over the EPA LTO cycle. CO reduction was 82 percent, UHC reduction was 96 percent, and smoke reduction was 84 percent. NOx increased 14 percent over the LTO cycle. At high power, NOx reduction was 40 to 55 percent. This NOx reduction has potential application to stationary gas turbine powerplants which have different EPA regulations. (Author)

**A77-28574 \*** Fan inlet disturbances and their effect on static acoustic data. K. L. Bekofsky, R. E. Sheer, and J. C. F. Wang (General Electric Co., Schenectady, N.Y.). *American Society of Mechanical Engineers, Gas Turbine Conference and Products Show, Philadelphia, Pa., Mar. 27-31, 1977, Paper 77-GT-63.* 9 p. 16 refs. Members, \$1.50; nonmembers, \$3.00. Contract No. NAS3-17853.

There is evidence that measurements of fan-rotor inlet noise taken during static test situations are at variance with aircraft engine flight data. In particular, static tests generally yield a significantly higher tone at blade passing frequency than that measured during flight. An experimental program was carried out to investigate this discrepancy. Inlet ground vortices and large-scale inlet turbulence were generated intentionally in an anechoic test chamber. Far-field acoustic measurements and inlet flow field hot film mappings of a fan rotor were then carried out to study the influence of such inlet disturbances at a static test facility. Experimental results indicate that the acoustic effect of such disturbances appears to be less severe for supersonic than for subsonic tip speeds. Further, a reverse flow that occurs on the exterior cowl in static test facilities appears to be an additional prime candidate for creating inlet disturbances and causing variance between flight and static acoustic data. (Author)

**A77-38607 \* #** Measured effects of coolant injection on the performance of a film cooled turbine. J. D. McDonel and J. E. Eiswerth (General Electric Co., Aircraft Engine Group, Evendale, Ohio). *American Institute of Aeronautics and Astronautics and Society of Automotive Engineers, Propulsion Conference, 13th, Orlando, Fla., July 11-13, 1977, AIAA Paper 77-946*. 8 p. 9 refs. Contract No. NAS3-16732.

Tests have been conducted on a 20-inch diameter single-stage air-cooled turbine designed to evaluate the effects of film cooling air on turbine aerodynamic performance. The present paper reports the results of five test configurations, including two different cooling designs and three combinations of cooled and solid airfoils. A comparison is made of the experimental results with a previously published analytical method of evaluating coolant injection effects on turbine performance. (Author)

**A77-51029 \* #** Theoretical jet exhaust noise model for the duct burning turbofan. R. S. Larson (United Technologies Corp., Pratt and Whitney Aircraft Group, East Hartford, Conn.). *American Institute of Aeronautics and Astronautics, Aeroacoustics Conference, 4th, Atlanta, Ga., Oct. 3-5, 1977, Paper 77-1264*. 13 p. 22 refs. Contract No. NAS3-17866.

A model was developed to predict the acoustic power spectrum for a Duct Burning Turbofan (DBTF) whose cycle results in a high velocity, high temperature fan stream and a lower velocity, lower temperature primary stream. Model tests have demonstrated that a DBTF may produce substantially less noise than a conventional turbojet with the same thrust and weight flow. Predictions from the model agreed well with measured data from the model tests. The characteristics of the DBTF acoustic power spectrum were shown to be related to the rapid mixing of the fan and primary streams. The effects of fan to primary velocity ratio, temperature ratio, area ratio, and the effect of nozzle geometry on DBTF jet noise were determined. (Author)

**A77-51084 \* #** Effects of forward motion on jet and core noise. J. K. C. Low (Douglas Aircraft Co., Inc., Long Beach, Calif.). *American Institute of Aeronautics and Astronautics, Aeroacoustics Conference, 4th, Atlanta, Ga., Oct. 3-5, 1977, Paper 77-1330*. 15 p. 20 refs. Contract No. NAS3-20031. (DOUGLAS-6616)

A study was conducted to investigate the effects of forward motion on both jet and core noise. Measured low-frequency noise from static-engine and from flyover tests with a DC-9-30 powered by JT8D-109 turbofan engines and with a DC-10-40 powered by JT8D-59A turbofan engines was separated into jet- and core noise components. Comparisons of the static and the corresponding in-flight jet- and core-noise components are presented. The results indicate that for the DC-9 airplane at low power settings, where core noise is predominant, the effect of convective amplification on core-noise levels is responsible for the higher in-flight low-frequency noise levels in the inlet quadrant. Similarly, it was found that for the DC-10 airplane with engines mounted under the wings and flaps and flap deflection greater than 30 degrees, the contribution from jet-flap-interaction noise is as much as 5 dB in the inlet quadrant and is responsible for higher in-flight low-frequency noise levels during approach conditions. Those results indicate that to properly investigate flight effects, it is important to consider the noise contributions from other low-frequency sources, such as the core and the jet-flap interaction. (Author)

## **08 AIRCRAFT STABILITY AND CONTROL**

Includes aircraft handling qualities; piloting; flight controls; and autopilots.

**N77-26163\*** National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio.

### **EXPLORATORY INVESTIGATION OF THE INCIPIENT SPINNING CHARACTERISTICS OF A TYPICAL LIGHT GENERAL AVIATION AIRPLANE**

Richard J. Ransudo [1977] 43 p refs

(NASA-TM-X-73671; E-9190) Avail: NTIS HC A03/MF A01 CSCL 01C

The incipient spinning characteristics of general aviation airplanes were studied. Angular rates in pitch, yaw, and roll were measured through the stall during the incipient spin and throughout the recovery along with control positions, angle of attack, and angle of sideslip. The characteristic incipient spinning motion was determined from a given set of entry conditions. The sequence of recovery controls were varied at two distinct points during the incipient spin, and the effect on recovery characteristics was examined. Aerodynamic phenomena associated with flow over the aft portion of the fuselage, vertical stabilizer, and rubber are described. Author



## 09 RESEARCH AND SUPPORT FACILITIES (AIR)

Includes airports, hangars and runways; aircraft repair and overhaul facilities; wind tunnels; shock tube facilities; and engine test blocks.

For related information see also 14 Ground Support Systems and Facilities (Space).

**N77-10073\*** National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio.

### A HIGH PRESSURE, HIGH TEMPERATURE COMBUSTOR AND TURBINE-COOLING TEST FACILITY

Reeves P. Cochran and James W. Norris 1976 30 p refs Presented at Winter Ann. Meeting of the Am. Soc. of Mechanical Engineers, New York, 28 Nov. - 3 Dec. 1976

(NASA-TM-X-73445; E-8801) Avail: NTIS HC A03/MF A01 CSCL 14B

A new test facility is being constructed for developing turbine-cooling and combustor technology for future generation aircraft gas turbine engines. Prototype engine hardware will be investigated in this new facility at gas stream conditions up to 2480 K average turbine inlet temperature and  $4.14 \times 10$  to the 6th power n sq m turbine inlet pressure. The facility will have the unique feature of fully automated control and data acquisition through the use of an integrated system of mini-computers and programmable controllers which will result in more effective use of operating time, will limit the number of operators required, and will provide built in self protection safety systems. The facility and the planning and design considerations are described.

Author

**N77-17108\*** National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio.

### THE LEWIS RESEARCH CENTER GEOMAGNETIC SUBSTORM SIMULATION FACILITY

Frank D. Berkopec, N. John Stevens, and John C. Sturman 1976 8 p refs Presented at Spacecraft Charging Technology Conf., Colorado Springs, Colo., 27-29 Oct. 1976; sponsored by the USAF and NASA

(NASA-TM-X-73602; E-8970-3) Avail: NTIS HC A02/MF A01 CSCL 14B

A simulation facility was established at the NASA-Lewis Research Center to determine the response of typical spacecraft materials to the geomagnetic substorm environment and to evaluate instrumentation that will be used to monitor spacecraft system response to this environment. Space environment conditions simulated included the thermal-vacuum conditions of space, solar simulation, geomagnetic substorm electron fluxes and energies, and the low energy plasma environment. Measurements for spacecraft material tests included sample currents, sample surface potentials, and the cumulative number of discharges. Discharge transients were measured by means of current probes and oscilloscopes and were verified by a photomultiplier.

Author

**N77-18168\*** National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio.

### CHARACTERISTICS OF AN ANECHOIC CHAMBER FOR FAN NOISE TESTING

Joseph A. Wuzniak, Loretta M. Shaw, and Jefferson D. Essary 1977 32 p refs Presented at the Intern. Gas Turbine Conf., Philadelphia, 26-30 Mar. 1977; sponsored by the Am. Soc. of Mech. Engrs.

(NASA-TM-X-73555; E-8993) Avail: NTIS HC A03/MF A01 CSCL 14B

Acoustical and mechanical design features of NASA Lewis Research Center's engine fan noise facility are described. Acoustic evaluation of the chamber, which is lined with an array of stepped wedges, is described. Results from the evaluation in terms of cut-off frequency and non-anechoic areas near the walls are detailed. Fan models are electrically driven to 20,600 RPM in

either the inlet mode or exhaust mode to facilitate study of both fore and aft fan noise. Inlet noise characteristics of the first fan tested are discussed and compared to full-scale levels. Turbulence properties of the inlet flow and acoustic results are compared with and without a turbulence reducing screen over the fan inlet.

Author

**N77-27149\*** National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio.

### THE PANEL ON PROPULSION AERODYNAMICS

David Bowditch in NASA Langley Res. Center High Reynolds Number Res. 1977 p 165-171 (For primary document see N77-27139 18-09)

Avail: NTIS HC A09/MF A01 CSCL 14B

Sources of discrepancies noted between propulsion aerodynamic characteristics as predicted from wind tunnel tests and as measured in flight are discussed. The variable Reynolds capability of the National Transonic Facility will provide a tool for understanding and quantifying uncertainties involved in extrapolating the corrected wind tunnel data from tunnel conditions to full scale flight conditions.

Author

**A77-26460 \*** A high-pressure, high-temperature combustor and turbine-cooling test facility. R. P. Cochran, J. W. Norris, and R. E. Jones (NASA, Lewis Research Center, Cleveland, Ohio). *American Society of Mechanical Engineers, Winter Annual Meeting, New York, N.Y., Dec. 5-10, 1976, Paper 76-WA/GT-4*. 11 p. 7 refs. Members, \$1.50; nonmembers, \$3.00.

NASA-Lewis Research Center is presently constructing a new test facility for developing turbine-cooling and combustor technology for future generation aircraft gas turbine engines. Prototype engine hardware will be investigated in this new facility at gas stream conditions up to 2480 K average turbine inlet temperature and  $4,140,000$  N per sq m turbine inlet pressure. The facility will have the unique feature of fully-automated control and data acquisition through the use of an integrated system of minicomputers and programmable controllers, which will result in more effective use of operating time, will limit the number of operators required, and will provide a built-in self-protection safety system. The paper describes the facility and the planning and design considerations involved.

(Author)

**A77-26814 \*** Advances in turbine blade temperature measurements. F. G. Pollack (NASA, Lewis Research Center, Cleveland, Ohio). In: *Advances in test measurement. Volume 13 - Proceedings of the Twenty-second International Instrumentation Symposium, San Diego, Calif., May 25-27, 1976. (A77-26776 11-35)* Pittsburgh, Pa., Instrument Society of America, 1976, p. 393-397.

Radiation pyrometry principles and imaging methods like photography and photoelectric scanning are combined to make accurate research quality temperature measurements on turbine airfoils. Two systems are described for obtaining detailed temperature distribution measurements: an infrared photographic system for stationary vanes and a photoelectric scanning system for rotating blades. An overview is presented outlining the design, calibration methods, and recent test results.

(Author)

**A77-26838 \*** A microprocessor controlled pressure scanning system. R. C. Anderson (NASA, Lewis Research Center, Cleveland, Ohio). In: *Advances in test measurement. Volume 13 - Proceedings of the Twenty-second International Instrumentation Symposium, San Diego, Calif., May 25-27, 1976. (A77-26776 11-35)* Pittsburgh, Pa., Instrument Society of America, 1976, p. 685-693.

A microprocessor-based controller and data logger for pressure scanning systems is described. The microcomputer positions and manages data from as many as four 48-port electro-mechanical pressure scanners. The maximum scanning rate is 80 pressure measurements per second (20 ports per second on each of four

scanners). The system features on-line calibration, position-directed data storage, and once-per-scan display in engineering units of data from a selected port. The system is designed to be interfaced to a facility computer through a shared memory. System hardware and software are described. Factors affecting measurement error in this type of system are also discussed. (Author)

**A77-26585 \* #** Characteristics of an anechoic chamber for fan noise testing. J. A. Wazyniak, L. M. Shaw, and J. D. Essary (NASA, Lewis Research Center, Cleveland, Ohio). *American Society of Mechanical Engineers, Gas Turbine Conference and Products Show, Philadelphia, Pa., Mar. 27-31, 1977, Paper 77-GT-74*. 12 p. 15 refs. Members, \$1.50; nonmembers, \$3.00.

Acoustical and mechanical design features of NASA Lewis Research Center's engine fan noise facility are described. Acoustic evaluation of the 1420-m (50,000-ft) chamber, which is lined with an array of stepped wedges, is described. Results from the evaluation in terms of cut-off frequency and non anechoic areas near the walls are detailed. Fan models with 0.51-m (20-in) diameters are electrically driven to 20,600 rpm in either the inlet mode (drawing air from the chamber) or exhaust mode (discharging air into the chamber) to facilitate study of both fore and aft fan noise. Inlet noise characteristics of the first fan tested, the JT8D Refan, are discussed and compared to full-scale levels. Turbulence properties of the inlet flow and acoustic results are compared with and without a turbulence reducing screen over the fan inlet. (Author)

## 12 ASTRONAUTICS (GENERAL)

For extraterrestrial exploration see 91 Lunar and Planetary Exploration.

**A77-38550\*** A candidate mission using the Shuttle and solar electric propulsion. J. H. Duxbury (California Institute of Technology, Jet Propulsion Laboratory, Spacecraft Studies Group, Pasadena, Calif.) and R. C. Finke (NASA, Lewis Research Center, Spacecraft Technology Div., Cleveland, Ohio). In: Space shuttle missions of the 80's; Proceedings of the Twenty-first Annual Meeting, Denver, Colo., August 26-28, 1975. Part 2. (A77-38526 16-12) San Diego, Calif., American Astronautical Society, 1977, p. 789-797. 9 refs. (AAS 75-163)

It is suggested that an out-of-the-ecliptic solar electric propulsion (SEP) mission be performed. Data would be gathered pertaining to the three-dimensional structure of solar features at radio and X-ray wavelengths, the properties of the solar wind as a function of latitude and time, the configuration of the interplanetary field and its relation to solar fields, and the modulations of cosmic rays to determine the spectrum of interstellar cosmic rays. The mission would also, it is thought, demonstrate the capability of SEP for use in Shuttle missions. The SEP spacecraft and the ongoing development of related systems are examined. The weight of a SEP stage is contrasted with the weight of a chemical rocket stage. M.L.

**N77-13090\*#** National Bureau of Standards, Washington, D.C. **SPACELAB EXPERIMENT DEFINITION STUDY ON PHASE TRANSITION AND CRITICAL PHENOMENA IN FLUIDS: INTERIM REPORT ON EXPERIMENTAL JUSTIFICATION** M. R. Moldover, M. R. Hocken, R. W. Gammon, and J. V. Sengers Aug. 1976 89 p refs Prepared in cooperation with Maryland Univ., College Park (NASA Order C-62861-C) (NASA-CR-135070) Avail: NTIS HC A05/MF A01 CSCL 22A

Pure fluids and fluid mixtures near critical points are identified and are related to the progress of several disciplines. Consideration is given to thermodynamic properties, transport properties, and the complex nonlinear phenomena which occur when fluids undergo phase transitions in the critical region. The distinction is made between practical limits which may be extended by advances in technology and intrinsic ones which arise from the modification of fluid properties by the earth's gravitational field. The kinds of experiments near critical points which could best exploit the low gravity environment of an orbiting laboratory are identified. These include studies of the index of refraction, constant volume specific heat, and phase separation. Author

**N77-33222\*#** Lockheed Missiles and Space Co., Huntsville, Ala. Research and Engineering Center. **SPACE PROCESSING APPLICATIONS OF ION BEAM TECHNOLOGY Final Report** P. G. Grodzka 15 Aug. 1977 41 p refs (Contract NAS3-20095) (NASA-CR-135261) Avail: NTIS HC A03/MF A01 CSCL 20L

Ion thruster engines for spacecraft propulsion can serve as ion beam sources for potential space processing applications. The advantages of space vacuum environments and the possible gravity effects on thruster ion beam materials operations such as thin film growth, ion milling, and surface texturing were investigated. The direct gravity effect on sputter deposition and vapor deposition processes are discussed as well as techniques for cold and warm welding. Author

# 13 ASTRODYNAMICS

Includes powered and free-flight trajectories; end orbit and launching dynamics.

**A77-28823 \*** Trajectory optimization for the Atlas/Centaur launch vehicle. R. G. Brusch (General Dynamics Corp., Convair Div., San Diego, Calif.). In: Conference on Decision and Control and Symposium on Adaptive Processes, 15th, Clearwater, Fla., December 1-3, 1976, Proceedings. (A77-28801 12-63) New York, Institute of Electrical and Electronics Engineers, Inc., 1976, p. 492-500. 41 refs. Contract No. NAS3-16094.

A state-of-art survey of computational techniques employed in design and optimization of trajectories for the Atlas/Centaur launch vehicle is presented. Attention is focused on the constrained optimization technique, related to Hestenes' (1969) method of multipliers, with various formulas used in updating the multipliers. Advantages of applying multiplier method to trajectory optimization, with gains in computing speed, are argued, and optimization of the HEAO-A (high energy astronomical observatory) is discussed. Open-loop atmospheric guidance strategy and closed-loop exoatmospheric pitch and yaw guidance equations are dealt with, and the full range of constraints to be observed during the flight is discussed.

R.D.V.

**A77-44872 \* #** Trajectory optimization for the Atlas/Centaur launch vehicle. R. G. Brusch (General Dynamics Corp., Convair Div., San Diego, Calif.). *Journal of Spacecraft and Rockets*, vol. 14, Sept. 1977, p. 550-555. 19 refs. Contract No. NAS3-16094.

A method for finding solutions to complex trajectory optimization problems with detailed hardware and launch vehicle constraints is presented. The trajectory optimization problem is formulated as a constrained function minimization problem by modeling the control by a function of a finite number of parameters. Although any parametric control model may be selected, the natural choice of parameters is the actual parameters of the parametric guidance equations flown on the flight digital computer. A variation of the method of multipliers is presented for performing the constrained function minimization. A functional is proposed that allows incorporation of state variable inequality constraints. Finally, optimization of the HEAO-A direct-ascent trajectory is discussed. The HEAO-A mission demonstrates profile optimization to meet range safety, tracking, heating, structural integrity, and attitude rate constraints.

(Author)

## 14 GROUND SUPPORT SYSTEMS AND FACILITIES (SPACE)

Includes launch complexes, research and production facilities; ground support equipment, mobile transporters; and simulators.

For related information see also 03 Research Support Facilities (Air).

**N77-15056\***# National Aeronautics and Space Administration, Lewis Research Center, Cleveland, Ohio.

### **USER GUIDE TO A COMMAND AND CONTROL SYSTEM: A PART OF A PRELAUNCH WIND MONITORING PROGRAM**

Glenn R. Cowgill Nov. 1976 29 p

(NASA-TM-X-73558; E-8999) Avail: NTIS HC A03/MF A01 CSCL 14B

A set of programs called Command and Control System (CCS), intended as a user manual, is described for the operation of CCS by the personnel supporting the wind monitoring portion of the launch mission. Wind data obtained by tracking balloons is sent by electronic means using telephone lines to other locations. Steering commands are computed from a system called ADDJUST for the on-board computer and relays this data. Data are received and automatically stored in a microprocessor, then via a real time program transferred to the UNIVAC 1100/40 computer. At this point the data is available to be used by the Command and Control system.

Author

### **N77-19132\***# Westinghouse Electric Corp., Pittsburgh, Pa. **DESIGN, FABRICATION AND TEST OF PROTOTYPE FURNACE FOR CONTINUOUS GROWTH OF WIDE SILICON RIBBON Final Report**

C. S. Duncan and R. G. Seidensticker Dec. 1976 117 p refs (Contract NAS3-19439)

(NASA-CR-135165; Rept-76-9C4-SIGRO-R1) Avail: NTIS HC A06/MF A01 CSCL 14B

A program having the overall objective of growing wide, thin silicon dendritic web crystals quasi-continuously from a semi-automated facility is discussed. The design considerations and fabrication of the facility as well as the test and operation phase are covered; detailed engineering drawings are included as an appendix. During the test and operation phase of the program, more than eighty growth runs and numerous thermal test runs were performed. At the conclusion of the program, 2.4 cm wide web was being grown at thicknesses of 100 to 300 micrometers. As expected, the thickness and growth rate are closely related. Solar cells made from this material were tested at NASA-Lewis and found to have conversion efficiencies comparable to devices fabricated from Czochralski material.

Author

# 15 LAUNCH VEHICLES AND SPACE VEHICLES

Includes boosters; manned orbital laboratories; reusable vehicles; and space stations.

**N77-10116\*** National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio.

## PRELIMINARY REPORT ON THE CTS TRANSIENT EVENT COUNTER PERFORMANCE THROUGH THE 1976 SPRING ECLIPSE SEASON

N. John Stevens, Robert R. Lovell, and Vernon W. Klinec 1976 28 p refs Presented at Spacecraft Charging Conf., Colorado Springs, 27-29 Oct. 1976; sponsored by AF (NASA-TM-X-73487; E-8879) Avail: NTIS HC A03/MF A01 CSDL 228

The transient event counter (TEC), senses and counts transients having a voltage rise of greater than five volts in three separate wire harnesses: the attitude control harness, the solar array instrumentation harness and the solar array power harness. The operational characteristics of TEC are defined and the preliminary results obtained through the first 90 days of operation including the spring 1976 eclipse season are presented. The results show that the Communications Technology Satellite was charged to the point where discharges occurred. The discharge induced transients did not cause any anomalous events in spacecraft operation. The data indicate that discharges can occur at any time during the day without preference to any local time quadrant. The number of discharges occurring in the one second sample interval are greater than anticipated. The compilation and review of the data is continuing. Author

**N77-10117\*** National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio.

## CTS UNITED STATES EXPERIMENTS. A PROGRESS REPORT

W. H. Robbins and P. L. Donoughe 1976 16 p refs Presented at the 27th Intern. Astronautical Congr., Anaheim, Calif., 10-16 Oct. 1976; sponsored by Intern. Astronautical Federation (NASA-TM-X-73510; E-8918) Avail: NTIS HC A02/MF A01 CSDL 228

The results are presented of the United States experiments activity to date. Wide segments of the population are involved in the Experiments Program including the scientific community, other government agencies, industry, and the education and health entities. The experiments are associated with both technological objectives and the demonstration of new community and social services via satellite. Author

**N77-10119\*** National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio.

## PROVISIONAL SPECIFICATION FOR SATELLITE TIME IN A GEOMAGNETIC SUBSTORM ENVIRONMENT

N. John Stevens, Robert R. Lovell, and Carolyn E. Purvis 1976 14 p refs Presented at joint Air Force NASA Spacecraft Charging Conf., Colorado Springs, Colo., 27-29 Oct. 1976 (NASA-TM-X-73446) Avail: NTIS HC A02/MF A01 CSDL 22A

Satellites in geosynchronous orbit have been experiencing operational anomalies. These anomalies are believed to be due to the environment charging the spacecraft surfaces to a point where discharges occur. In designing future satellites for long term operation at geosynchronous altitude, it is important that designers have a specification that will give the total time per year, the particle flux density, and particle energies that their satellites can be expected to encounter in these substorm environmental conditions. The limited data currently available on the environmental conditions was used to generate the provisional specification given. Author

**N77-12099\*** National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio.

## PURGING OF A MULTILAYER INSULATION WITH DACRON TUFT SPACER BY GAS DIFFUSION

Irving E. Sumner and William J. Fisk Washington Dec. 1976 28 p refs (NASA-TM-X-3456; E-8833) Avail: NTIS HC A03/MF A01 CSDL 11D

The time and purge gas usage required to purge a multilayer insulation (MLI) panel with gaseous helium by means of gas diffusion to obtain a condensable gas (nitrogen) concentration of less than 1 percent within the panel are stipulated. Two different, flat, rectangular MLI panels, one incorporating a butt joint, were constructed of 11 double-aluminized Mylar (DAM) radiation shields separated by Dacron tuft spacers. The DAM/Dacron tuft concept is known commercially as Superfloc. The nitrogen gas concentration as a function of time within the MLI panel could be adequately predicted by using a simple, one dimensional gas diffusion model in which the boundary conditions at the edge of the MLI panel were time dependent. The time and purge gas usage required to achieve 1 percent nitrogen gas concentration within the MLI panel varied from 208 to 86 minutes and 34.1 to 56.5 MLI panel purge volumes, respectively, for gaseous helium purge rates from 10 to 40 MLI panel volumes per hour. Author

**N77-15063\*** National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio.

## OPTIMAL REUSABLE-TUG AND EXPENDABLE-KICKSTAGE TRAJECTORIES FOR HIGH-ENERGY PLANETARY MISSIONS INCLUDING CORRECTION FOR NODAL PRECESSION

Janos Borsody Washington Dec. 1976 48 p refs (NASA-TN-D-8387; E-8844) Avail: NTIS HC A03/MF A01 CSDL 22B

Equations are derived by using branched trajectory optimization techniques and the maximum principle to maximize the payload capability of a reusable tug/expendable kickstage vehicle configuration for planetary missions. The two stages and the payload are launched into a low earth orbit by a single space shuttle. The analysis includes correction for precession of the orbit. This correction is done by the tug. The tug propels the payload and the kickstage to an energy beyond earth escape and returns within a specified time to the precessed orbit. After separating from the tug, the kickstage accelerates the payload to the required injection conditions. Planetary injection conditions are specified by the mission energy and a fixed declination and right ascension of the outgoing asymptote. The multipoint boundary value problem resulting from the analysis is solved by a Newton-Raphson iteration technique. Partial derivatives of the boundary conditions are obtained by perturbing the initial conditions one at a time, integrating the trajectory and adjoint equations, and observing the changes in boundary conditions. Maximum payload capability is derived for two typical mission energies. In addition, the variations of several mission and stage parameters are also examined. Author

**N77-18182\*** National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio.

## THERMODYNAMIC DATA REPORT FOR THE TITAN/CENTAUR TC-5 EXTENDED MISSION

Raymond F. Lacombe Jan. 1977 47 p (NASA-TM-X-73605; E-9080) Avail: NTIS HC A03/MF A01 CSDL 22B

The Titan/Centaur vehicle, with the Helios B spacecraft, was launched on January 15, 1976. After the spacecraft was placed into its desired heliocentric trajectory, the Centaur vehicle continued into an extended mission to perform experiments demonstrating increased operational capabilities. The thermal performance of all pertinent Centaur systems and components was evaluated and its capability for satisfactory operation for long duration space coasts was verified. The selected thermal control techniques maintained the Centaur component temperatures within their qualification limits for the entire 8-hour and 22-minute duration of the extended mission. Author

**N77-28183\*** National Aeronautics and Space Administration.  
Lewis Research Center, Cleveland, Ohio.  
**ON-ORBIT PERFORMANCE OF THE 12 GHz, 200 WATT  
TRANSMITTER EXPERIMENT PACKAGE FOR CTS**  
Robert E. Alexovich 1977 9 p refs Presented at Intern.  
Conf. on Communications, Chicago, 12-15 Jun. 1977; sponsored  
by IEEE  
(NASA-TM-X-73836) Avail: NTIS HC A02/MF A01 CSCL  
22A

Performance characteristics from on-orbit tests of the transmitter experiment package (TEP) for the Communications Technology Satellite (CTS) are presented. The TEP consists of a power processing system (PPS), an output stage tube (OST) and a variable conductance heat pipe system (VCHPS), all of which are described. Test results presented include efficiencies, RF output power, frequency response, and performance with single and multiple (two) carriers, frequency-modulated by video signals.  
Author

**N77-33232\*** National Aeronautics and Space Administration.  
Lewis Research Center, Cleveland, Ohio.  
**PROPELLANT MANAGEMENT REPORT FOR THE TITAN  
CENTAUR TC-8 EXTENDED MISSION**  
Raymond Lacovic 1977 43 p  
(NASA-TM-73749; E-9365) Avail: NTIS HC A03/MF A01  
CSCL 22B

An extended mission was conducted to perform experiments demonstrating increased operational capabilities. The Centaur propellant behavior, the effects of reduced tank pressurization levels, and a propellant duct prechill technique were successfully evaluated. The major flight data results show that: (1) the propellants can be controlled with short collection times, even with a simulated H2O2 engine failure; (2) extensive tank venting can be safely performed; (3) the Centaur boost pumps can perform adequately with no LH2 tank pressurization, and with low LO2 tank pressurization levels; (4) the duct prechill technique is an effective way to reduce boost pump cavitation and improve engine shutdown; and (5) the Centaur boost pumps should be completely stopped prior to an engine start sequence.  
Author

**N77-30166\*** Dayton Univ. Research Inst., Ohio.  
**COMPENDIUM OF APPLICATIONS TECHNOLOGY SATEL-  
LITE USER EXPERIMENTS Final Report, 1967-1973**  
Nicholas A. Engler, Jerry D. Strange, and Gerald F. Hein Aug.  
1976 247 p refs Prepared in cooperation with NASA, Lewis  
Res. Center  
(Contract NAS3-19699)  
(NASA-CR-135057) Avail: NTIS HC A11/MF A01 CSCL  
22A

The achievements of the user experiments performed with ATS satellites from 1967 to 1973 are summarized. Included are fixed and mobile point to point communications experiments involving voice, teletype and facsimile transmissions. Particular emphasis is given to the Alaska and Hawaii satellite communications experiments. The use of the ATS satellites for ranging and position fixing of ships and aircraft is also covered. The structure and operating characteristics of the various ATS satellite are briefly described.  
Author

## 16 SPACE TRANSPORTATION

Includes passenger and cargo space transportation e.g., shuttle operations; and rescue techniques.

For related information see also 03 Air Transportation and Safety and 85 Urban Technology and Transportation.

N77-15085\*# McDonnell-Douglas Astronautics Co., Huntington Beach, Calif.

### SPACELAB CRYOGENIC PROPELLANT MANAGEMENT EXPERIMENT Special Report, Jun. - Nov. 1976

E. C. Cady Nov. 1976 63 p refs

(Contract NAS3-19719)

(NASA-CR-135143: MDC-G6552)

Avail: NTIS

HC A04/MF A01 CSCL 22B

The conceptual design of a Spacelab cryogen management experiment was performed to demonstrate the desirability and feasibility of subcritical cryogenic fluid orbital storage and supply. A description of the experimental apparatus, definition of supporting requirements, procedures, data analysis, and a cost estimate are included.

Author



# 17 SPACECRAFT COMMUNICATIONS, COMMAND AND TRACKING

Includes telemetry; space communications networks; astronavigation; and radio blackout.

For related information see also 04 Aircraft Communications and Navigation and 32 Communications.

**A77-33256\*** National Aeronautics and Space Administration, Lewis Research Center, Cleveland, Ohio.

## EARLY PERFORMANCE OF THE 12-GHz, 200-WATT TRANSMITTER EXPERIMENT PACKAGE IN THE COMMUNICATIONS TECHNOLOGY SATELLITE

Washington Oct. 1977 66 p refs  
(NASA-TM-X-3555; E-9104) Avail. NTIS HC AD4/MF A01 CSCL 17B

Measured performance characteristics of the transmitter experiment package (TEP) aboard the Communications Technology Satellite for the first 90 operating days in orbit are presented. The TEP consists of a nominal 200-watt output stage tube (OST), a supporting power processing system (PPS), and a variable-conductance heat pipe system (VCHPS). The OST, a traveling-wave tube augmented with a 10-stage depressed collector, has an overall saturated average efficiency of 51.5 percent and an average saturated radiofrequency (RF) output power at center-band frequency of 240 watts. The PPS operated with a measured efficiency of 86.5 percent to 88.5 percent. The VCHPS, using three pipes to conduct heat from the PPS and the body of the OST to a 62-centimeter by 124-centimeter (20.5-in. by 48.75-in.) radiator fin, maintained by the PPS baseplate temperature below 60 C for all operating conditions. The TEP performance characteristics presented include frequency response, RF output power, efficiency, and distortions. Communications characteristics were evaluated by using both video and audio modulated signals.

Author

**A77-12987\*** Long lifetime hollow cathodes for 30-cm mercury ion thrusters. M. J. Mirtich and W. R. Kerslake (NASA, Lewis Research Center, Cleveland, Ohio). *American Institute of Aeronautics and Astronautics, International Electric Propulsion Conference, Key Biscayne, Fla., Nov. 14-17, 1976, Paper 76-985*. 16 p. 25 refs.

An experimental investigation of hollow cathodes for 30-cm Hg bombardment thrusters was carried out. Both main and neutralizer cathode configurations were tested with both rolled foil inserts coated with low work function material and impregnated porous tungsten inserts. Temperature measurements of an impregnated insert at various positions in the cathode were made. These, along with the cathode thermal profile are presented. A theory for rolled foil and impregnated insert operation and lifetime in hollow cathodes is developed. Several endurance tests, as long as 18,000 hours at emission currents of up to 12 amps were attained with no degradation in performance.

(Author)

**A77-12988\*** Cycle life testing of 8-cm mercury ion thruster cathodes. E. G. Wintucky (NASA, Lewis Research Center, Cleveland, Ohio). *American Institute of Aeronautics and Astronautics, International Electric Propulsion Conference, Key Biscayne, Fla., Nov. 14-17, 1976, Paper 76-986*. 14 p. 11 refs.

Two main cathodes have successfully completed 2800 and 1980 cycles and three neutralizers, 3928, 3050, and 2850 cycles in

ongoing cycle life tests of flight-type cathode-isolator-vaporizer and neutralizer-isolator-vaporizer assemblies for the 4.45 mN 8-cm Hg ion thruster system. Each cycle included one hour of cathode operation. Starting and operating conditions simulated those expected in a typical auxiliary propulsion mission duty cycle. This paper presents the cycle life test results and also results of an insert comparison test which led to the selection of a rolled foil insert type for the 8-cm Engineering Model Thruster cathodes.

(Author)

**A77-47953\*** On-orbit performance of the 12 GHz, 200 watt transmitter experiment package for CTS. R. E. Alexovich (NASA, Lewis Research Center, Cleveland, Ohio). *Institute of Electrical and Electronics Engineers, International Conference on Communications, Chicago, Ill., June 12-15, 1977, Paper*. 8 p. 6 refs.

Performance characteristics from on-orbit tests of the Transmitter Experiment Package (TEP) for the Communications Technology Satellite (CTS) are presented. The TEP consists of a Power Processing System (PPS), an Output Stage Tube (OST), and a Variable Conductance Heat Pipe System (VCHPS), all of which are described. The OST is a coupled-cavity traveling-wave tube with a multistage depressed collector and a stepped velocity-tapered slow-wave structure for efficiency enhancement. It has an RF output power of 240 W and an overall efficiency of 51.5% at a center band frequency of 12.080 GHz. The PPS provides the required operating voltages, regulation, control, and protection for the OST. It has a measured dc-dc conversion efficiency of 86.5% to 88.5%. The VCHPS consists of a fin radiator and three dual-artery stainless steel heat pipes using methanol and a mixture of inert gases. Test results presented include efficiencies, RF output power, frequency response, and performance with single and multiple (two) carriers frequency-modulated by video signals.

(Author)

# 18 SPACECRAFT DESIGN, TESTING AND PERFORMANCE

Includes spacecraft thermal and environmental control; and attitude control.

For life support systems see 54 *Man/System Technology and Life Support*. For related information see also 05 *Aircraft Design, Testing and Performance* and 39 *Structural Mechanics*.

**N77-10141\*** National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio.

## ENVIRONMENTAL CHARGING TESTS OF SPACECRAFT THERMAL CONTROL LOUVERS

F. D. Berkopac, N. J. Stevens, F. W. Schmidt, and R. A. Blech  
Sep. 1976 38 p refs  
(NASA-TM-X-73517; E-8927) Avail: NTIS HC A03/MF A01 CSCL 22B

The environmental charging of spacecraft surfaces program consists, in part, of experimental evaluation of material response to the environmental charged particle flux. A flight type spacecraft thermal control louver assembly has been tested in an electron flux. The louver blade surface potential, the louver assembly currents, and the relatively high number of discharges observed in the electron environment are self-consistent results. The unexpected result of this testing was the flutter observed when the louvers were closed. The flutter is about 1 to 2 Hz in frequency and is probably electrostatically induced. Author

**N77-16106\*** National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio.

## THERMAL PERFORMANCE OF A MODULARIZED REPLACEABLE MULTILAYER INSULATION SYSTEM FOR A CRYOGENIC STAGE

Richard H. Knoll Washington Jan. 1977 71 p refs  
(NASA-TN-D-8282; E-8809) Avail: NTIS HC A04/MF A01 CSCL 22A

A rugged modularized MLI system for a 2.23-meter-diameter (87.6-in.-diam) liquid hydrogen tank was designed, fabricated, and tested under simulated near-earth and deep-space environments. The two blankets of the system were each composed of 17 double-aluminized Mylar radiation shields separated by silk net. The unit area weight of the installed system was 1.54 kg/sqm (0.32 lb/sq ft). The overall average heat transferred into the insulated tank was 22.7 and 0.98 watts (77.4 and 3.3 Btu/hr) during simulated near-earth and deep-space testing, respectively. The near-earth result was only 2.6 times that predicted for an undisturbed insulation system (i.e., no seams or penetrations). Tests indicate that this insulation concept could be useful for a cryogenic space tug or orbit transfer vehicle application. Author

**N77-18202\*** National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio.

## TESTING OF TYPICAL SPACECRAFT MATERIALS IN A SIMULATED SUBSTORM ENVIRONMENT

N. John Stephens, Frank D. Berkopac, John V. Staskus, Richard A. Blech, and Steven J. Narciso 1976 27 p refs Presented at the Spacecraft Charging Technology Conf., Colorado Springs, 27-29 Oct. 1976; cosponsored by the USAF and NASA  
(NASA-TM-X-73603; E-8970-4) Avail: NTIS HC A03/MF A01 CSCL 22B

An investigation to determine spacecraft materials characteristics under charging conditions was conducted at the Lewis Research Center substorm simulation facility. The test specimens were spacecraft paints, silvered Teflon, thermal blankets and solar array segments. The samples, ranging in size from 300 to 1,000 sq cm were exposed to monoenergetic electron energies from 2 to 20 keV at a current density of 1 nA/sq cm. The samples generally behaved as capacitors with strong voltage gradients at their edges. The charging characteristics of the silvered Teflon, Kapton, and solar cell covers were controlled by the secondary emission characteristics. Insulators that did not

discharge were the spacecraft paints and the quartz fiber cloth thermal blanket sample. All other samples did experience discharges when the surface voltage reached -8 to -16 kV. The discharges were photographed. The breakdown voltage for each sample was determined and the average energy lost in the discharge was computed. Author

**N77-19158\*** National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio.

## MASS STUDY FOR MODULAR APPROACHES TO A SOLAR ELECTRIC PROPULSION MODULE

G. Richard Sharp, James E. Cake, Jan C. Oglebay, and Francis J. Shaker Mar. 1977 37 p refs  
(NASA-TM-X-3473; E-8800) Avail: NTIS HC A03/MF A01 CSCL 21C

The propulsion module comprises six to eight 30-cm thruster and power processing units, a mercury propellant storage and distribution system, a solar array ranging in power from 18 to 25 kW, and the thermal and structure systems required to support the thrust and power subsystems. Launch and on-orbit configurations are presented for both modular approaches. The propulsion module satisfies the thermal design requirements of a multimission set including: Mercury, Saturn, and Jupiter orbiters, a 1-AU solar observatory, and comet and asteroid rendezvous. A detailed mass breakdown and a mass equation relating the total mass to the number of thrusters and solar array power requirement is given for both approaches. Author

**N77-19159\*** National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio.

## DESIGN, FABRICATION, AND STRUCTURAL TESTING OF A LIGHTWEIGHT SHADOW SHIELD FOR DEEP-SPACE APPLICATION

David Miao, James R. Barber, and Richard L. DeWitt Washington Mar. 1977 51 p refs  
(NASA-TN-D-8319; E-8889) Avail: NTIS HC A04/MF A01 CSCL 22A

Two full-scale, lightweight, double-sheeted shadow shields were developed as the primary element of a deep-space thermal protection system for liquid-hydrogen propellant tankage. The thermal and mechanical considerations used in the method of fabrication, and the environmental testing results on a prototype shield are discussed. Testing consisted of a transient cooldown period, a prolonged cold soak, and a transient warmup. The mechanical and thermal analyses used in the shield design are sufficient to produce a lightweight rugged shadow shield assembly that is structurally adequate for its intended application. Author

**N77-19160\*** National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio.

## CHARGING CHARACTERISTICS OF MATERIALS: COMPARISON OF EXPERIMENTAL RESULTS WITH SIMPLE ANALYTICAL MODELS

Carolyn K. Purvis, N. John Stevens, and Jan C. Oglebay 1977 29 p refs Presented at the Spacecraft Charging Technol. Conf., Colorado Springs, Colo., 27-29 Oct. 1976; cosponsored by NASA and AF  
(NASA-TM-X-73606; E-8970-2) Avail: NTIS HC A03/MF A01 CSCL 22B

An understanding of the behavior of materials, of dielectrics in particular, under charged particle bombardment is essential to the prediction and prevention of the adverse effects of spacecraft charging. A one-dimensional model for charging of samples in a test facility was used in conjunction with experimental data taken to develop 'material charging characteristics' for silvered Teflon. These characteristics were then used in a one-dimensional model for charging in space to examine expected response. Relative charging rates as well as relative charging levels for silvered Teflon and metal are discussed. Author

**N77-24183\*** National Aeronautics and Space Administration,  
Lewis Research Center, Cleveland, Ohio.

**THERMAL PERFORMANCE OF AN INTEGRATED THERMAL  
PROTECTION SYSTEM FOR LONG-TERM STORAGE OF  
CRYOGENIC PROPELLANTS IN SPACE**

Richard L. DeWitt and Robert J. Boyle Washington May 1977  
109 p refs

(NASA-TN-D-8320: E8881) Avail: NTIS HC A06/MF A01  
CSCL 22B

It was demonstrated that cryogenic propellants can be stored unvented in space long enough to accomplish a Saturn orbiter mission after 1,200-day coast. The thermal design of a hydrogen-fluorine rocket stage was carried out, and the hydrogen tank, its support structure, and thermal protection system were tested in a vacuum chamber. Heat transfer rates of approximately 23 W were measured in tests to simulate the near-Earth portion of the mission. Tests to simulate the majority of the time the vehicle would be in deep space and sun-oriented resulted in a heat transfer rate of 0.11 W.

Author

**A77-12530\*** # Spacecraft charging investigation - A joint research and technology program. R. R. Lovell, N. J. Stevens (NASA, Lewis Research Center, Cleveland, Ohio), W. Schober (USAF, Space and Missile Systems Organization, El Segundo, Calif.), C. P. Pike (USAF, Geophysics Laboratory, Bedford, Mass.), and W. Lehn (USAF, Materials Laboratory, Wright-Patterson AFB, Ohio). In: Spacecraft charging by magnetospheric plasmas; Symposium, Washington, D.C., June 16-19, 1975, Technical Papers. (A77-12529 02-18) New York, American Institute of Aeronautics and Astronautics, Inc.; Cambridge, Mass., MIT Press, 1976, p. 3-14. 5 refs.

A jointly planned U.S. Air Force-NASA program has been established to investigate the spacecraft charging phenomenon that has caused electronic anomalies in satellites in geosynchronous orbits. The objectives of this program are to provide design criteria, techniques, and test methods to insure control of absolute and differential charging of spacecraft surfaces. These objectives will be updated continuously over the next four years as data become available from the combined contractual and in-house programs. The geosynchronous altitude environment will be defined, ground and flight tests will be conducted, and materials and charge control techniques will be developed as required. The ultimate output of the program will be a spacecraft charging design criteria and test specification document. The program will be coordinated by a spacecraft charging program review group which has both Air Force and NASA representation.

(Author)

## 19 SPACECRAFT INSTRUMENTATION

For related information see also 06 Aircraft Instrumentation and 35 Instrumentation and Photography.

**N77-10148\*** National Aeronautics and Space Administration, Lewis Research Center, Cleveland, Ohio.

### ION BEAM THRUSTER SHIELD Patent

John L. Power, inventor (to NASA) Issued 5 Oct. 1976 8 p  
Filed 12 Sep 1975 Supersedes N75-32166 (13 - 23,  
p 2886)

(NASA-Case-LEW-12082-1: US-Patent-3,983,695;  
US-Patent-Appl-SN-612964: US-Patent-Class-60-202;  
US-Patent-Class-313-361: US-Patent-Class-313-231 4;  
US-Patent-Class-313-240: US-Patent-Class-315-111.3) Avail.  
US Patent Office CSCL 21C

An ion thruster beam shield is provided that comprises a cylindrical housing that extends downstream from the ion thruster and a plurality of annular vanes which are spaced along the length of the housing, and extend inwardly from the interior wall of the housing. The shield intercepts and stops all charge exchange and beam ions, neutral propellant, and sputter products formed due to the interaction of beam and shield emanating from the ion thruster outside of a fixed conical angle from the thruster axis. Further, the shield prevents the sputter products formed during the operation of the engine from escaping the interior volume of the shield.

Official Gazette of the U.S. Patent Office

**N77-10149\*** National Aeronautics and Space Administration, Lewis Research Center, Cleveland, Ohio.

### STATUS OF SERT 2 THRUSTERS AND SPACECRAFT 1976

William R. Kerslake 1976 12 p refs Proposed for presentation at Intern. Elec. Propulsion Conf., Key Biscayne, Fla., 15-17 Nov. 1976; sponsored by AIAA

(NASA-TM-X-73501) Avail: NTIS HC A02/MF A01 CSCL 21C

The historical record of the SERT II ion thrusters and spacecraft performance for 6 1/2 years since the February 1970 launch is reviewed. The most recent ion thruster operation test shows no changes since 1974. Thruster 2 is fully operational with no performance degradation. Thruster 1 has a high voltage grid short, but continues to demonstrate cathode and discharge re-light capability. Spacecraft orbit and dynamic analysis indicates a stable, sun-synchronous spacecraft orientation by 1979. An attitude adjustment maneuver was performed in August 1976 to achieve this orientation and provide sufficient continuous solar power for thruster operation in 1979.

Author

**N77-17141\*** National Aeronautics and Space Administration, Lewis Research Center, Cleveland, Ohio.

### DEVELOPMENT OF ENVIRONMENTAL CHARGING EFFECT MONITORS FOR OPERATIONAL SATELLITES

N. John Stevens, John C. Sturman, and Frank D. Berkopce 1976 7 p refs Presented at the Spacecraft Charging Technology Conf., Colorado Springs, Colo., 27-29 Oct. 1976; sponsored by the USAF and NASA

(NASA-TM-X-73601: E-8970-5) Avail: NTIS HC A02/MF A01 CSCL 14B

An instrumentation package to monitor the effects of the environmental charging of spacecraft surfaces on the systems of operational spacecraft was developed. This package performs two functions: first, the local charged particle flux and the particle characteristic energy is monitored; and second, transients in the spacecraft electrical harness is counted as a function of amplitude,

with time. It is used to determine the duration and effect of any environmental charging of the spacecraft surfaces. Thus, it will be possible to determine the relationship between the occurrence of any anomalies and the charging phenomenon. Design details and design goals of this package are presented.

Author

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### THE 6870-NEWTON ATTITUDE-CONTROL THRUSTER USING HYDROGEN-OXYGEN PROPELLANT

Larry H. Gordon Washington May 1977 39 p refs  
(NASA-TM-X-3523: E-8981) Avail: NTIS HC A03/MF A01 CSCL 21H

The development of a reusable, attitude-control propulsion system for the space transportation system is discussed. A flight weight, gaseous oxygen attitude control thruster assembly was tested to obtain data on cyclic life, thermal and hydraulic characteristics, pulse response, and performance. The basic thruster components were tested in excess of 51,000 pulses and 860 seconds, steady state, with no degradation of the 93 percent characteristic exhaust velocity efficiency level. Nominal operating conditions were a chamber pressure of 207 N/sq cm (300 psia), a mixture ratio of 4.0, a pulse width of 100 ms, and a pulse frequency of 2 Hz.

Author

## 20 SPACECRAFT PROPULSION AND POWER

Includes main propulsion systems and components e.g. rocket engines; and spacecraft auxiliary power sources.

For related information see also 07 Aircraft Propulsion, 28 Propellants and Fuels, and 44 Energy Production and Conversion.

**N77-10150\*#** National Aeronautics and Space Administration, Lewis Research Center, Cleveland, Ohio.

### A 30-cm DIAMETER ARGON ION SOURCE

J. S. Sovoy 1976 16 p refs Presented at 12th Intern. Elec. Propulsion Conf., Key Biscayne, Fla., 15-17 Nov. 1976, sponsored by AIAA

(NASA-TM-X-73509: E-8917) Avail: NTIS HC A02/MF A01 CSCL 21C

A 30 cm diameter argon ion source was evaluated. Ion source beam currents up to 4a were extracted with ion energies ranging from 0.2 to 1.5 KeV. An ion optics scaling relation was developed for predicting ion beam extraction capability as a function of total extraction voltage, gas type, and screen grid open area. Ignition and emission characteristics of several hollow cathode geometries were assessed for purposes of defining discharge chamber and neutralizer cathodes. Also presented are ion beam profile characteristics which exhibit broad beam capability well suited for ion beam sputtering applications.

Author

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### MODULAR THRUST SUBSYSTEM APPROACHES TO SOLAR ELECTRIC PROPULSION MODULE DESIGN

James E. Cake, G. Richard Sharp, John C. Oglebay, Francis J. Shaker, and Ralph J. Zavesky 1976 25 p refs Presented at the 12th Intern. Elec. Propulsion Conf., Key Biscayne, Fla., 15-17 Nov. 1976, sponsored by AIAA

(NASA-TM-X-73502: E-8800) Avail: NTIS HC A02/MF A01 CSCL 21C

Three approaches are presented for packaging the elements of a 30 cm ion thruster subsystem into a modular thrust subsystem. The individual modules, when integrated into a conceptual solar electric propulsion module are applicable to a multimission set of interplanetary flights with the space shuttle interim upper stage as the launch vehicle. The emphasis is on the structural and thermal integration of the components into the modular thrust subsystems. Thermal control for the power processing units is either by direct radiation through louvers in combination with heat pipes or an all heat pipe system. The propellant storage and feed system and thruster gimbal system concepts are presented. The three approaches are compared on the basis of mass, cost, testing, interfaces, simplicity, reliability, and maintainability.

Author

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### HIGH DENSITY PROPELLANT FOR SINGLE STAGE TO ORBIT VEHICLES

J. J. Notardonato and Philip A. Masters 1976 15 p refs Proposed for presentation at the JANNAF Propulsion Meeting, Atlanta, 7-9 Dec. 1976

(NASA-TM-X-73503: E-8850) Avail: NTIS HC A02/MF A01 CSCL 22B

Mixed mode propulsion concepts are studied for advanced, single stage earth orbital transportation systems (SSTO) for use in the post-1990 time period. These propulsion concepts are based on the sequential and/or parallel use of high density impulse and high specific impulse propellants in a single stage to increase vehicle performance and reduce dry weight. Specifically, the mixed mode concept utilizes two propulsion systems with two

different fuels (mode 1 and mode 2) with liquid oxygen as a common oxidizer. Mode 1 engines would burn a high bulk density fuel for lift-off and early ascent to minimize performance penalties associated with carrying fuel tankage to orbit. Mode 2 engines will complete orbital injection utilizing liquid hydrogen as the fuel

Author

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### STATUS OF 30-CENTIMETER-DIAMETER MERCURY ION THRUSTER ISOLATOR DEVELOPMENT

M. A. Manteniaks 1976 12 p refs Presented at 12th Intern. Electric Propulsion Conf., Key Biscayne, Fla., 15-17 Nov. 1976; sponsored by AIAA

(NASA-TM-X-73514: E-8921) Avail: NTIS HC A02/MF A01 CSCL 21C

Results are presented of several 30 cm diameter mercury ion thruster isolator life tests that show that the onset and exponential increase of leakage current problems observed in earlier thruster operations and isolator tests have been solved. A 10,006 hour life test of a main isolator vaporizer operated with no mercury flow at 320 C and 1500 volts was found to have no onset of leakage current during the test. A cathode-isolator vaporizer operated with a mercury discharge at 340 to 360 C and 1200 volts for 18,000 hours, was found to have a small increase of leakage current with time. A 10,000 hour thruster life test exhibited no increase of leakage current during the life test. Isolators have been developed which will satisfy 30 cm mercury ion thruster mission requirements.

Author

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### A THRUST-SHEET PROPULSION CONCEPT USING FISSIONABLE ELEMENTS

W. E. Moeckel 1976 13 p refs Presented at Intern. Electric Propulsion Conf., Key Biscayne, Fla., 14-17 Nov. 1976; sponsored by AIAA

(NASA-TM-X-73469) Avail: NTIS HC A02/MF A01 CSCL 21H

A space propulsion concept is proposed and analyzed which consists of a thin sheet coated on one side with fissionable material, so that nuclear power is converted directly into propulsive power. Thrust is available both from ejected fission fragments and from thermal radiation. Optimum thicknesses are determined for the active and substrate layers. This concept is shown to have potential mission capability (in terms of velocity increments) superior to that of all other advanced propulsion concepts for which performance estimates are available. A suitable spontaneously fissioning material such as Cf254 could provide an extremely high-performance first stage beyond earth orbit. In contrast with some other advanced nuclear propulsion concepts, there is no minimum size below which this concept is infeasible.

Author

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### A 15,000-HOUR CYCLIC ENDURANCE TEST OF AN 8-CENTIMETER-DIAMETER ELECTRON BOMBARDMENT MERCURY ION THRUSTER

Shigeo Nakanishi 1976 37 p refs Presented at the 12th Intern. Elec. Propulsion Conf., Key Biscayne, Fla., 15-17 Nov. 1976; sponsored by AIAA

(NASA-TM-X-73508: E-886) Avail: NTIS HC A03/MF A01 CSCL 21C

A laboratory model 8 cm thruster with improvements to minimize ion chamber erosion and peeling of sputtered metal was subjected to a cyclic endurance test for 15,040 hours and 460 restarts. A charted history of several thruster operating variables and off-normal events are shown in 600-hour segments at three points in the test. The transient behavior of these variables

during a typical start-stop cycle is presented. Finding of the post-test inspection confirmed most of the expected results. Charge exchange ions caused normal accelerator grid erosion. The workability of the various design features was substantiated, and attainable improvements in propellant utilization efficiency should significantly reduce accelerator erosion. Author

**N77-11100\*** National Aeronautics and Space Administration, Lewis Research Center, Cleveland, Ohio.

**COMPENSATED CONTROL LOOPS FOR A 30-cm ION THRUSTER**

R. R. Robson 1976 17 p refs Presented at the 12th Intern Elec. Propulsion Conf., Key Biscayne, Fla., 15-17 Nov 1976; sponsored by AIAA (NASA-TM-X-73497, E-8895) Avail: NTIS HC A02/MF A01 CSCL 21C

The vaporizer dynamic control characteristics of a 30-cm diameter mercury ion thruster were determined by operating the thruster in an open loop steady state mode and then introducing a small sinusoidal signal on the main, cathode, or neutralizer vaporizer current and observing the response of the beam current, discharge voltage, and neutralizer keeper voltage, respectively. This was done over a range of frequencies and operating conditions. From these data, Bode plots for gain and phase were made and mathematical models were obtained. The Bode plots and mathematical models were analyzed for stability and appropriate compensation networks determined. The compensated control loops were incorporated into a power processor and operated with a thruster. The time responses of the compensated loops to changes in set points and recovery from arc conditions are presented. Author

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**LONG LIFETIME HOLLOW CATHODES FOR 30-cm MERCURY ION THRUSTERS**

Michael J. Mirtich and William R. Kerslake 1976 22 p refs Presented at the 12th Intern. Elec. Propulsion Conf., Key Biscayne, Fla., 15-17 Nov. 1976; sponsored by AIAA (NASA-TM-X-73523; E-8937) Avail: NTIS HC A02/MF A01 CSCL 21C

An experimental investigation of hollow cathodes for 30-cm Hg bombardment thrusters was carried out. Both main and neutralizer cathode configurations were tested with both rolled foil inserts coated with low work function material and impregnated porous tungsten inserts. Temperature measurements of an impregnated insert at various positions in the cathode were made. These, along with the cathode thermal profile are presented. A theory for rolled foil and impregnated insert operation and lifetime in hollow cathodes is developed. Several endurance tests, as long as 18000 hours at emission currents of up to 12 amps were attained with no degradation in performance. Author

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**CYCLE LIFE TESTING OF 8-cm MERCURY ION THRUSTER CATHODES**

Edwin G. Wintucky 1976 21 p refs Presented at the 12th Intern. Elec. Propulsion Conf., Key Biscayne, Fla., 15-17 Nov. 1976; sponsored by AIAA (NASA-TM-X-73526, E-8942) Avail: NTIS HC A02/MF A01 CSCL 21C

Two main cathodes have successfully completed 2800 and 1980 cycles and three neutralizers, 3928, 3050, and 2850 cycles in ongoing cycle life tests of flight-type cathode-isolator-vaporizer and neutralizer-isolator-vaporizer assemblies for the 4.45 mN 8-cm Hg ion thruster system. Each cycle included one hour of cathode operation. Starting and operating conditions simulated those expected in a typical auxiliary propulsion mission duty cycle. The cycle life test results are presented along with results of an insert comparison test which led to the selection of a rolled foil insert type for the 8-cm Engineering Model Thruster cathodes. Author

**N77-11103\*** National Aeronautics and Space Administration, Lewis Research Center, Cleveland, Ohio.

**PERFORMANCE DOCUMENTATION OF THE ENGINEERING MODEL 30-cm DIAMETER THRUSTER**

Robert T. Bechtel and Vincent K. Rawlin 1976 35 p Presented at the 12th Intern. Elec. Propulsion Conf., Key Biscayne, Fla., 15-17 Nov. 1976; sponsored by AIAA (NASA-TM-X-73530, E-8952) Avail: NTIS HC A03/MF A01 CSCL 21C

The results of extensive testing of two 30-cm ion thrusters which are virtually identical to the 900 series Engineering Model Thruster in an ongoing 15,000-hour life test are presented. Performance data for the nominal fullpower (2650 W) operating point: performance sensitivities to discharge voltage, discharge losses, accelerator voltage, and magnetic baffle current, and several power throttling techniques (maximum Isp, maximum thrust/power ratio, and two cases in between are included). Criteria for throttling are specified in terms of the screen power supply envelope, thruster operating limits, and control stability. In addition, reduced requirements for successful high voltage recycles are presented. Author

**N77-11104\*** National Aeronautics and Space Administration, Lewis Research Center, Cleveland, Ohio.

**SPUTTERING PHENOMENA OF DISCHARGE CHAMBER COMPONENTS IN A 30-cm DIAMETER Hg ION THRUSTER**

Maris A. Mantenieks and Vincent K. Rawlin 1976 23 p refs Presented at the 12th Intern. Elec. Propulsion Conf., Key Biscayne, Fla., 15-17 Nov., 1976; sponsored by AIAA (NASA-TM-X-73533; E-8957) Avail: NTIS HC A02/MF A01 CSCL 21C

Sputtering and deposition rates were measured for discharge chamber components of a 30-cm diameter mercury ion thruster. It was found that sputtering rates of the screen grid and cathode baffle were strongly affected by geometry of the baffle holder. Sputtering rates of the baffle and screen grid were reduced to 80 and 125 A/hr, respectively, by combination of appropriate geometry and materials selections. Sputtering rates such as these are commensurate with thruster lifetimes of 15,000 hours or more. A semiempirical sputtering model showed good agreement with the measured values. Author

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**HIGH RELIABILITY CATHODE HEATERS FOR ION THRUSTERS**

Lawrence A. Mueller 1976 16 p refs Presented at the 12th Intern. Elec. Propulsion Conf., Key Biscayne, Florida, 15-17 Nov 1976; sponsored by AIAA (NASA-TM-X-73538, E-8966) Avail: NTIS HC A02/MF A01 CSCL 21C

A number of space missions were proposed which utilize 30-cm mercury bombardment ion thrusters and also require a large number of thruster restarts. A test program was carried out to determine thermal cycle life of several different cathode heater designs. Plasma/flame sprayed heaters and swaged type heaters were tested. Four of the five plasma/flame sprayed heaters tested failed in a comparatively short time. Four tantalum swaged heaters that were brazed to the tantalum cathode tube were successfully tested and met the goals that were set at the start of the test. Author

**N77-11106\*** National Aeronautics and Space Administration, Lewis Research Center, Cleveland, Ohio.

**ELECTRON BOMBARDMENT PROPULSION SYSTEM CHARACTERISTICS FOR LARGE SPACE SYSTEMS**

D. C. Byers and V. K. Rawlin 1976 33 p refs Presented at the 12th Intern. Elec. Propulsion Conf., Key Biscayne, Fla., 15-17 Nov 1976; sponsored by AIAA (NASA-TM-X-73554, E-8992) Avail: NTIS HC A03/MF A01 CSCL 21C

The results of an analysis of electron bombardment ion propulsion systems for use in the transportation and on-orbit operations of large space systems are presented. Using baseline

technology from the ongoing primary propulsion program and other sources, preliminary estimates of the expected characteristics of key system elements such as thrusters and propellant storage systems were performed. Projections of expected thruster performance on argon are presented based on identified constraints which limit the achievable thrust and/or power density of bombardment thrusters. System characteristics are then evaluated as a function of thruster diameter and specific impulse.

Author

**N77-12121\*** National Aeronautics and Space Administration, Lewis Research Center, Cleveland, Ohio.  
**THERMAL-ENVIRONMENT TESTING OF A 30-cm ENGINEERING MODEL THRUSTER**

Michael J. Mirtich 1976 23 p refs Presented at the 12th Intern. Elec Propulsion Conf., Key Biscayne, Fla., 15-17 Nov. 1976; sponsored by AIAA  
(NASA-TM-X-73522; E-8936) Avail: NTIS HC A02/MF A01 CSCL 21C

An experimental test program was carried out to document all 30-cm electron bombardment Hg ion bombardment thruster functions and characteristics over the thermal environment of several proposed missions. An engineering model thruster was placed in a thermal test facility equipped with -196 C walls and solar simulation. The thruster was cold soaked and exposed to simulated eclipses lasting in duration from 17 to 72 minutes. The thruster was operated at quarter, to full beam power in various thermal configurations which simulated multiple thruster operation, and was also exposed to 1 and 2 suns solar simulation. Thruster control characteristics and constraints: performance, including thrust magnitude and direction, and structural integrity were evaluated over the range of thermal environments tested.

Author

**N77-16108\*** National Aeronautics and Space Administration, Lewis Research Center, Cleveland, Ohio.  
**LIQUID ROCKET ENGINE NOZZLES NASA Space Vehicle Design Criteria (Chemical Propulsion)**

Washington Jul. 1976 120 p refs  
(NASA-SP-8120) Avail: NTIS HC A06/MF A01 CSCL 21H

The nozzle is a major component of a rocket engine, having a significant influence on the overall engine performance and representing a large fraction of the engine structure. The design of the nozzle consists of solving simultaneously two different problems: the definition of the shape of the wall that forms the expansion surface, and the delineation of the nozzle structure and hydraulic system. This monography addresses both of these problems. The shape of the wall is considered from immediately upstream of the throat to the nozzle exit for both bell and annular (or plug) nozzles. Important aspects of the methods used to generate nozzle wall shapes are covered for maximum-performance shapes and for nozzle contours based on criteria other than performance. The discussion of structure and hydraulics covers problem areas of regeneratively cooled tube-wall nozzles and extensions; it treats also nozzle extensions cooled by turbine exhaust gas, ablation-cooled extensions, and radiation-cooled extensions. The techniques that best enable the designer to develop the nozzle structure with as little difficulty as possible and at the lowest cost consistent with minimum weight and specified performance are described.

Author

**N77-20182\*** National Aeronautics and Space Administration, Lewis Research Center, Cleveland, Ohio.  
**ANODE FOR ION THRUSTER Patent**

Bruce A. Banks, inventor (to NASA) Issued 15 Mar. 1977 4 p Filed 8 Mar. 1976 Supersedes N76-19227 (14 - 10, p 1228)

(NASA-Case-LEW-12048-1; US-Patent-4,011,719;  
US-Patent-Appl-SN-665033; US-Patent-Class-60-202;  
US-Patent-Class-313-230; US-Patent-Class-313-231.3;  
US-Patent-Class-313-360; US-Patent-Class-315-111.3;

of stainless steel wire cloth with a mesh size less than the intergrid gap or openings of the screen grid or accelerator grid systems of the ion thruster. The screen anode is sputter coated with tantalum as a result of thruster operation. Because of the fineness of the screen anode any spalled material from the tantalum coated anode is in such small dimensions that the spalled pieces cannot interfere with the accelerator and screen grid systems and with the focusing therebetween.

Official Gazette of the U.S. Patent Office

**N77-20163\*** National Aeronautics and Space Administration, Lewis Research Center, Cleveland, Ohio.  
**GRAPHICAL METHOD FOR PREDICTING LIFE OF A ROCKET THRUST CHAMBER WITH HALF-HARD ZIRCONIUM-COPPER LINER AND ELECTROFORMED NICKEL CLOSEOUT**

Harold J. Kasper Washington Mar. 1977 29 p refs  
(NASA-TM-X-3499; E-8971) Avail: NTIS HC A03/MF A01 CSCL 21H

A method for estimating the life of a regeneratively cooled rocket thrust chamber was developed and is based on the hot-gas wall temperature and the temperature difference between the hot-gas wall and the outside surface of the closeout. This method permits a quick estimate of the life of a thrust chamber when design changes or test-cycle variations are considered. Strain range and life are presented graphically as functions of these temperature parameters for a typical high-performance rocket thrust chamber with a half-hard zirconium-copper liner and an electroformed nickel closeout.

Author

**N77-25244\*** National Aeronautics and Space Administration, Lewis Research Center, Cleveland, Ohio.  
**COMPARISON OF THERMAL ANALYTIC MODEL WITH EXPERIMENTAL TEST RESULTS FOR 30-CENTIMETER-DIAMETER ENGINEERING MODEL MERCURY ION THRUSTER**

Jon C. Oglebay Washington Jun. 1977 33 p refs  
(NASA-TM-X-3541; E-9064) Avail: NTIS HC A03/MF A01 CSCL 21C

A thermal analytic model for a 30-cm engineering model mercury-ion thruster was developed and calibrated using the experimental test results of tests of a pre-engineering model 30-cm thruster. A series of tests, performed later, simulated a wide range of thermal environments on an operating 30-cm engineering model thruster, which was instrumented to measure the temperature distribution within it. The modified analytic model is described and analytic and experimental results compared for various operating conditions. Based on the comparisons, it is concluded that the analytic model can be used as a preliminary design tool to predict thruster steady-state temperature distributions for stage and mission studies and to define the thermal interface between the thruster and other elements of a spacecraft.

Author

**N77-28222\*** National Aeronautics and Space Administration, Lewis Research Center, Cleveland, Ohio.  
**SOLAR ARRAY MAXIMUM POWER TRACKING WITH CLOSED-LOOP CONTROL OF A 30-CENTIMETER ION THRUSTER**

R. P. Gruber Mar. 1977 25 p refs  
(NASA-TM-X-73643; E-9148) Avail: NTIS HC A02/MF A01 CSCL 21C

A new solar array/ion thruster system control concept has been developed and demonstrated. An ion thruster beam load is used to automatically and continuously operate an unregulated solar array at its maximum power point independent of variations in solar array voltage and current. Preliminary tests were run which verified that this method of control can be implemented with a few, physically small, signal level components dissipating less than two watts.

Author

**N77-27185\*** National Aeronautics and Space Administration, Lewis Research Center, Cleveland, Ohio.  
**OPERATIONAL COMPATIBILITY OF 30-CENTIMETER-DIAMETER ION THRUSTER WITH INTEGRALLY REGULATED SOLAR ARRAY POWER SOURCE**  
 Suzanne T. Gooder Jul 1977 26 p refs  
 (NASA-TN-D-8428; E-9072) Avail: NTIS HC A03/MF A01 CSCL 21C

System tests were performed in which Integrally Regulated Solar Arrays (IRSA's) were used to directly power the beam and accelerator loads of a 30-cm-diameter, electron bombardment, mercury ion thruster. The remaining thruster loads were supplied from conventional power-processing circuits. This combination of IRSA's and conventional circuits formed a hybrid power processor. Thruster performance was evaluated at 3/4- and 1-A beam currents with both the IRSA-hybrid and conventional power processors and was found to be identical for both systems. Power processing is significantly more efficient with the hybrid system. System dynamics and IRSA response to thruster arcs are also examined.

Author

**N77-28218\*** National Aeronautics and Space Administration, Lewis Research Center, Cleveland, Ohio.  
**INTEGRALLY REGULATED SOLAR ARRAY DEMONSTRATION USING AN INTEL 8080 MICROPROCESSOR**  
 Edward J. Petrik Washington Jul 1977 17 p refs  
 (NASA-TM-X-3566; E-9144) Avail: NTIS HC A02/MF A01 CSCL 10A

A concept for regulating the voltage of a solar array by using a microprocessor to effect discrete voltage changes was demonstrated. Eight shunting switches were employed to regulate a simulated array at set-point voltages between 10,000 and 15,000 volts. The demonstration showed that the microprocessor easily regulated the solar array output voltage independently of whether or not the switched cell groups were binary sized in voltage. In addition, the microprocessor provided logic memory capability to perform additional tasks such as locating and insulating a faulty switch.

Author

**N77-30171\*** National Aeronautics and Space Administration, Lewis Research Center, Cleveland, Ohio.  
**SOLID ROCKET MOTOR INTERNAL INSULATION**  
 Sherwood E. Twitchell, ed. (Hercules, Inc., Wilmington, Del.) and Russell B. Keller, Jr. Dec. 1976 124 p refs  
 (NASA-SP-8093) Avail: NTIS HC A08/MF A01 CSCL 21H

Internal insulation in a solid rocket motor is defined as a layer of heat barrier material placed between the internal surface of the case propellant. The primary purpose is to prevent the case from reaching temperatures that endanger its structural integrity. Secondary functions of the insulation are listed and guidelines for avoiding critical problems in the development of internal insulation for rocket motors are presented.

B.B.

**N77-31238\*** National Aeronautics and Space Administration, Lewis Research Center, Cleveland, Ohio.  
**EXPERIMENTAL FATIGUE LIFE INVESTIGATION OF CYLINDRICAL THRUST CHAMBERS**  
 R. J. Quentmeyer Jul 1977 21 p refs Presented at 13th Propulsion Conf., Orlando, Fla., 11-13 Jul 1977; sponsored by AIAA and Soc. of Automotive Engineers  
 (NASA-TM-X-73665; E-9188) Avail: NTIS HC A02/MF A01 CSCL 21H

Twenty-two cylindrical test sections of a cylindrical rocket thrust chamber were fabricated and 21 of them were cycled to failure to explore the failure mechanisms, determine the effects of wall temperature on cyclic life, and to rank the material life characteristics for comparison with results from isothermal tests of 12 alloys at 538 C. Cylinder liners were fabricated from OFHC copper, Amzirc, and NARloy-Z. Tests were conducted at a chamber pressure of 4.14 MW/sq m using hydrogen-oxygen propellants at an oxidant-fuel ratio of 6.0, which resulted in an

average throat heat flux of 54 MW/sq m. The cylinders were cooled with liquid hydrogen at an average rate of 0.91 Kg/sec. All failures were characterized by a thinning of the cooling channel wall at the centerline and eventual failure by tensile rupture. Cyclic life rankings of the materials based on temperature do not agree with published rankings based on uniaxial, isothermal strain tests.

Author

**A77-12863\*** NASA thermionic-conversion program. J. F. Morris (NASA, Lewis Research Center, Thermionics and Heat-Pipe Section, Cleveland, Ohio) and J. G. Lundholm (NASA, Office of Aeronautics and Space Technology, Research Div., Washington, D.C.), In: Intersociety Energy Conversion Engineering Conference, 11th, State Line, Nev., September 12-17, 1976, Proceedings, Volume 2. (A77-12662 02-44) New York, American Institute of Chemical Engineers, 1976, p. 1652-1655.

The NASA applied research and technology (ART) program for thermionic energy conversion (TEC) is progressing effectively. Current out-of-core emphases allow converter material and design freedoms previously prohibited by in-core nucleonic and geometric restrictions. As a result, potential improvements indicate possibilities for severalfold increases in efficiencies. The new TEC-ART program concentrated initially on low-work-function collectors and inter-electrode-loss reduction and revealed much in a short time. For example, arc-drop studies verified the necessity of stable emitters that operate well with little or no adsorbed cesium. This new emission capability coupled with improved collectors that maintain performance with emitter-vapor deposit accumulations are requisites for efficient, enduring thermionic converters. The accomplishments and contributors in these areas are discussed.

(Author)

**A77-12990\*** Compensated control loops for a 30-cm ion thruster. R. R. Rotson (NASA, Lewis Research Center, Cleveland, Ohio). American Institute of Aeronautics and Astronautics, International Electric Propulsion Conference, Key Biscayne, Fla., Nov. 14-17, 1976, Paper 76-994, 14 p.

The vaporizer dynamic control characteristics of a 30-cm diameter mercury ion thruster were determined by operating the thruster in an open loop steady state mode and then introducing a small sinusoidal signal on the main, cathode, or neutralizer vaporizer current and observing the response of the beam current, discharge voltage, and neutralizer keeper voltage, respectively. This was done over a range of frequencies and operating conditions. From these data, Bode plots for gain and phase were made and mathematical models were obtained. The Bode plots and mathematical models were analyzed for stability and appropriate compensation networks determined. The compensated control loops were incorporated into a power processor and operated with a thruster. The time responses of the compensated loops to changes in set points and recovery from arc conditions are presented.

(Author)

**A77-13017\*** A thrust-sheet propulsion concept using fissionable elements. W. E. Moeckel (NASA, Lewis Research Center, Cleveland, Ohio). American Institute of Aeronautics and Astronautics, International Electric Propulsion Conference, Key Biscayne, Fla., Nov. 14-17, 1976, Paper 76-1042, 12 p, 22 refs.

A space propulsion concept is proposed and analyzed which consists of a thin sheet coated on one side with fissionable material, so that nuclear power is converted directly into propulsive power. Thrust is available both from ejected fission fragments and from thermal radiation. Optimum thicknesses are determined for the active and substrate layers. This concept is shown to have potential mission capability (in terms of velocity increments) superior to that of all other advanced propulsion concepts for which performance estimates are available. A suitable spontaneously fissioning material such as Cf-254 could provide an extremely high-performance first stage beyond earth orbit. In contrast with some other advanced nuclear propulsion concepts, there is no minimum size below which this concept is infeasible.

(Author)



**A77-13027 \* #** Status of SERT II thrusters and spacecraft - 1976. W. R. Kerlake (NASA, Lewis Research Center, Cleveland, Ohio). *American Institute of Aeronautics and Astronautics, International Electric Propulsion Conference, Key Biscayne, Fla., Nov. 14-17, 1976, Paper 76-1061*. 9 p. 8 refs.

The historical record of the SERT II ion thrusters and spacecraft performance for 6-1/2 years since the February 1970 launch is reviewed. The most recent ion thruster operation test shows no changes since 1974. Thruster 2 is fully operational with no performance degradation. Thruster 1 has a high voltage grid short, but continues to demonstrate cathode and discharge relight capability. Spacecraft orbit and dynamic analysis indicates a stable, sun-synchronous spacecraft orientation by 1979. An attitude adjustment maneuver was performed in August 1976 to achieve this orientation and provide sufficient continuous solar power for thruster operation in 1979. (Author)

**A77-13028 \* #** Modular thrust subsystem approaches to solar electric propulsion module design. J. E. Calk, G. R. Sharp, J. C. Oglebay, F. J. Shaker, and R. J. Zevosky (NASA, Lewis Research Center, Cleveland, Ohio). *American Institute of Aeronautics and Astronautics, International Electric Propulsion Conference, Key Biscayne, Fla., Nov. 14-17, 1976, Paper 76-1062*. 14 p. 10 refs.

Three approaches are presented for packaging the elements of a 30 cm ion thruster subsystem into a modular thrust subsystem. The individual modules, when integrated into a conceptual solar electric propulsion module are applicable to a multimission set of interplanetary flights with the Space Shuttle/Interim Upper Stage as the launch vehicle. The emphasis is on the structural and thermal integration of the components into the modular thrust subsystems. Thermal control for the power processing units is either by direct radiation through louvers in combination with heat pipes of an all heat pipe system. The propellant storage and feed system and thruster gimbal system concepts are presented. The three approaches are compared on the basis of mass, cost, testing, interfaces, simplicity, reliability, and maintainability. (Author)

**A77-15087 \* #** Sputtering phenomena of discharge chamber components in a 30-cm diameter Hg ion thruster. M. A. Manteniaks and V. K. Rawlin (NASA, Lewis Research Center, Cleveland, Ohio). *American Institute of Aeronautics and Astronautics, International Electric Propulsion Conference, Key Biscayne, Fla., Nov. 14-17, 1976, Paper 76-988*. 24 p. 30 refs.

Sputtering and deposition rates have been measured for discharge chamber components of a 30-cm diameter mercury ion thruster. It was found that sputtering rates of the screen grid and cathode baffle were strongly affected by geometry of the baffle holder. Sputtering rates of the baffle and screen grid were reduced to 80 and 125 A/hr, respectively, by combination of appropriate geometry and materials selections. Sputtering rates such as these are commensurate with thruster lifetimes of 15,000 hours or more. A semiempirical sputtering model showed good agreement with the measured values. (Author)

**A77-15096 \* #** An endurance test of a 900 series 30-cm engineering model ion thruster. C. R. Collett (Hughes Research Laboratories, Malibu, Calif.) and R. T. Bechtel (NASA, Lewis Research Center, Cleveland, Ohio). *American Institute of Aeronautics and Astronautics, International Electric Propulsion Conference, Key Biscayne, Fla., Nov. 14-17, 1976, Paper 76-1020*. 9 p. 9 refs. Contract No. NAS3-18914.

The 10,000 hour endurance test of the first engineering model 30-cm thruster (S/N 701) identified discharge chamber erosion as a life limiting problem. Modifications to minimize this problem have been implemented in the 900 series thrusters. This paper describes a test conducted to evaluate the success of these modifications. The post-test analysis results of thruster 701 are summarized and the erosion reducing modifications described. Test results for thruster 901 up to 4165 hours, when the test was interrupted by a shorted

wire, are described. The conclusions of a post-test examination of thruster 901 are included. Also being evaluated was a thermal vacuum breadboard SCR series inverter power processor which is described. (Author)

**A77-15099 \* #** Status of 30-centimeter-diameter mercury ion thruster isolator development. M. A. Manteniaks (NASA, Lewis Research Center, Cleveland, Ohio). *American Institute of Aeronautics and Astronautics, International Electric Propulsion Conference, Key Biscayne, Fla., Nov. 14-17, 1976, Paper 76-1027*. 12 p. 25 refs.

Results are presented for several 30-cm-diameter mercury-ion-thruster isolator life tests which show that the onset and exponential increase of leakage-current problems observed in earlier thruster operations and isolator tests have been solved. A 10,006-hour life test of a main isolator-vaporizer operated with no mercury flow at 320 C and 1500 volts was found to have no onset of leakage current during the test. A cathode-isolator-vaporizer (CIV) operated with a mercury discharge at 340 to 360 C and 1200 volts for 18,000 hours was found to have a small increase (0.004 micro A/hr) in leakage current with time. A 10,000-hour thruster life test exhibited no increase in leakage current during the life test. It is concluded that isolators have been developed which will satisfy 30-cm mercury-ion-thruster mission requirements. (Author)

**A77-15101 \* #** Performance documentation of the Engineering Model 30 cm diameter Thruster. R. T. Bechtel and V. K. Rawlin (NASA, Lewis Research Center, Cleveland, Ohio). *American Institute of Aeronautics and Astronautics, International Electric Propulsion Conference, Key Biscayne, Fla., Nov. 14-17, 1976, Paper 76-1033*. 36 p. 17 refs.

Presented are the results of extensive testing of two 30-cm ion thrusters which are virtually identical to the 900 series Engineering Model Thruster in an ongoing 15,000-hour life test. Included are performance data for the nominal full-power (2650 W) operating point; performance sensitivities to discharge voltage, discharge losses, accelerator voltage, and magnetic baffle current; and several power throttling techniques (maximum tsp, maximum thrust/power ratio, and two cases in between). Criteria for throttling are specified in terms of the screen power supply envelope, thruster operating limits, and control stability. In addition, reduced requirements for successful high voltage recycles are presented. (Author)

**A77-15103 \* #** Electron bombardment propulsion system characteristics for large space systems. D. C. Byers and V. K. Rawlin (NASA, Lewis Research Center, Cleveland, Ohio). *American Institute of Aeronautics and Astronautics, International Electric Propulsion Conference, Key Biscayne, Fla., Nov. 14-17, 1976, Paper 76-1039*. 34 p. 36 refs.

Presented are the results of an analysis of electron bombardment ion propulsion systems for use in the transportation and on-orbit operations of large space systems. Using baseline technology from the ongoing primary propulsion program and other sources, preliminary estimates of the expected characteristics of key system elements such as thrusters and propellant storage systems have been performed. Projections of expected thruster performance on argon are presented based on identified constraints which limit the achievable thrust and/or power density of bombardment thrusters. System characteristics are then evaluated as a function of thruster diameter and specific impulse. (Author)

**A77-23917 \* #** NASA 30,000 hour test demonstration of closed Brayton cycle reliability. J. E. McCormick (Air Research Manufacturing Company of Arizona, Phoenix, Ariz.) and J. H. Dunn (NASA, Lewis Research Center, Cleveland, Ohio). *American Institute of Aeronautics and Astronautics, Conference on the Future of Aerospace Power Systems, St. Louis, Mo., Mar. 1-3, 1977, Paper 77-491*. 3 p.

Four Brayton rotating units (BRU) developed by an American company were tested in connection with studies concerning the feasibility to use closed Brayton power conversion systems for space applications. The rotating assembly operates at a speed of 36,000 rpm and consists of a radial outflow compressor, a four-pole Rice alternator/motor, and a radial inflow turbine. The cycle working fluid consists of a mixture of helium and xenon. After 20,000 hours of operation, there was no apparent wear on failure mode to prevent attainment of the 5-year BRU design life objective. G.R.

**A77-23918 \* #** Thermionic energy conversion technology: Present and future. K. Shimada (California Institute of Technology, Jet Propulsion Laboratory, Pasadena, Calif.) and J. F. Morris (NASA, Lewis Research Center, Cleveland, Ohio). *American Institute of Aeronautics and Astronautics, Conference on the Future of Aerospace Power Systems, St. Louis, Mo., Mar. 1-3, 1977, Paper 77-500*. 8 p. 13 refs. Contract No. NAS7-100.

Aerospace and terrestrial applications of thermionic direct energy conversion and advances in direct energy conversion (DEC) technology are surveyed. Electrode materials, the cesium plasma drop (the difference between the barrier index and the collector work function), DEC voltage/current characteristics, conversion efficiency, and operating temperatures are discussed. Attention is centered on nuclear reactor system thermionic DEC devices, for in-core or out-of-core operation. Thermionic fuel elements, the radiation shield, power conditions, and a waste heat rejection system are considered among the thermionic DEC system components. Terrestrial applications include topping power systems in fossil fuel and solar power generation. R.D.V.

**A77-38559 \* #** Centaur propellant thermal conditioning system. M. H. Blatt (General Dynamics Corp., Convair Div., San Diego, Calif.) and J. C. Aydelott (NASA, Lewis Research Center, Cleveland, Ohio). *American Institute of Aeronautics and Astronautics and Society of Automotive Engineers, Propulsion Conference, 13th, Orlando, Fla., July 11-13, 1977, AIAA Paper 77-851*. 10 p. 14 refs. Contracts No. NAS3-17802; No. NAS3-19693.

An upgraded Centaur capability was studied by investigating three main areas: (1) Analytical and experimental investigation of promising capillary pumping concepts for passive cooling of cryogenic capillary acquisition devices resulted in selection, test, and empirical correlation of four wicking configurations. Only plate/screen-screen/plate and plate/screen-plate/screen configurations would function successfully under worst-case Centaur D-1S conditions. Weight estimates were developed for the passively cooled configurations and comparisons were made of passive and actively cooled capillary devices. (2) Thermal subcoolers for replacing pressurization and boost pump systems for three engine candidates and three Centaur D-1S missions were evaluated for several feed system configurations. Analysis included both transient and steady-state operation. Weight comparisons were made among feed system alternatives. (3) Existing experimental mixing studies to destroy thermal stratification were evaluated to determine the best mixing correlation to fit all available data. The correlation was then used to modify a computer program to size thermodynamic vent systems for Shuttle-based Centaur derivatives. (Author)

**A77-38580 \* #** Experimental fatigue life investigation of cylindrical thrust chambers. R. J. Quentmeyer (NASA, Lewis Research Center, Cleveland, Ohio). *American Institute of Aeronautics and Astronautics and Society of Automotive Engineers, Propulsion Conference, 13th, Orlando, Fla., July 11-13, 1977, AIAA Paper 77-893*. 16 p. 9 refs.

The thrust chambers studied in the investigation have been designed for a possible use in the Space Shuttle main engine. An annular combustion chamber configuration was used, consisting of an annular injector, a liquid hydrogen cooled outer cylinder, which served as the test section, and a contoured water cooled centerbody which formed the throat. Twenty-two cylinders were fabricated by

milling cooling channels into liners fabricated from the material to be evaluated. The three materials chosen for the liners include OFHC copper, Amzirc, and NARloy-Z. The cylinders were cyclically tested until failure occurred due to fatigue cracks in the hot-gas-side wall. It was found that cylinders with liners fabricated from NARloy-Z and aged Amzirc had the best cyclic life characteristics. G.R.

**N77-13143 \* #** Colorado State Univ., Fort Collins. Dept. of Mechanical Engineering. **ARGON HOLLOW CATHODE M.S. Thesis** Larry A. Rehn Nov. 1976 60 p refs (Grant NSG-3011) (NASA-CR-135102) Avail: NTIS HC A04/MF A01 CSCL 21C

An interest in alternate propellants for ion-bombardment thrusters, together with ground applications of this technology, has prompted consideration of argon. Several variations of conventional hollow cathode designs were tried, but the bulk of the testing used a hollow tube with an internal tungsten emitter and an orifice at one end. The optimum cathode tube diameter was found to be in the range of 1.0-2.5 cm, somewhat larger than those used for cesium and mercury. Optimum orifice diameter depended on operating conditions, and varied from 0.5 to 5 mm. Biasing the internal emitter negative relative to the cathode chamber reduced the external coupling voltage and should therefore improve orifice lifetime. The expected effect of this bias on emitter lifetime was less clear. Lifetime tests were not conducted as part of this investigation, but several designs show promise of long lifetime in specific applications. Author

**N77-14187 \* #** Physical Sciences, Inc., Woburn, Mass. **LASER-HEATED ROCKET STUDIES** Final Report, 28 Apr. 1975 - 28 Apr. 1976 N. H. Kemp, R. G. Root, P. K. S. Wu, G. E. Caledonia, and A. N. Pirri May 1976 127 p refs (Contract NAS3-19695) (NASA-CR-135127) PSI-TR-531 Avail: NTIS HC A07/MF A01 CSCL 21C

CW laser heated rocket propulsion was investigated in both the flowing core and stationary core configurations. The laser radiation considered was 10.6 micrometers, and the working gas was unseeded hydrogen. The areas investigated included initiation of a hydrogen plasma capable of absorbing laser radiation, the radiation emission properties of hot, ionized hydrogen, the flow of hot hydrogen while absorbing and radiating, the heat losses from the gas and the rocket performance. The stationary core configuration was investigated qualitatively and semi-quantitatively. It was found that the flowing core rockets can have specific impulses between 1,500 and 3,300 sec. They are small devices, whose heating zone is only a millimeter to a few centimeters long, and millimeters to centimeters in radius, for laser power levels varying from 10 to 5,000 kW, and pressure levels of 3 to 10 atm. Heat protection of the walls is a vital necessity, though the fraction of laser power lost to the walls can be as low as 10% for larger powers, making the rockets thermally efficient. Author

**N77-17148 \* #** Pratt and Whitney Aircraft Group, West Palm Beach, Fla. Government Products Div. **DEVELOPMENT OF SPUTTERED TECHNIQUES FOR THRUST CHAMBERS** Final Report J. R. Mullaly, R. J. Hecht, J. W. Broch, and P. A. Allard Nov. 1976 71 p refs (Contract NAS3-17792) (NASA-CR-135153; FR-8027) Avail: NTIS HC A04/MF A01 CSCL 21H

Procedures for closing out coolant passages in regeneratively cooled thrust chambers by triode sputtering, using post and hollow Cu-0.15 percent Zr cathodes are described. The effects of aluminum composite filler materials, substrate preparation, sputter cleaning, substrate bias current density and system geometry on closeout layer bond strength and structure are evaluated. High strength closeout layers were sputtered over aluminum fillers. The tensile strength and microstructure of continuously sputtered

Cu-0.15 percent Zr deposits were determined. These continuous sputtered deposits were as thick as 0.75 cm. Tensile strengths were consistently twice as great as the strength of the material in wrought form.

Author

discharge-chamber components and the incorporation of ion machined accelerators in the beam-extraction systems. Performance of the optimized modules are summarized.

Author

**N77-21189\*** Rocketdyne, Canoga Park, Calif.  
**AEROSPIKE THRUST CHAMBER PROGRAM Final Report**  
J. Campbell, Jr. and S. M. Cobb Dec. 1976 167 p refs  
(Contract NAS3-20076)  
(NASA-CR-135169; R76-189) Avail: NTIS HC A08/MF A01  
CSCL 21H

An existing, but damaged, 25,000-pound thrust, lightweight, oxygen/hydrogen aerospike rocket thrust chamber was disassembled and partially repaired. A description is presented of the aerospike chamber configuration and of the damage it had suffered. Techniques for aerospike thrust chamber repair were developed, and are described, covering repair procedures for lightweight tubular nozzles, titanium thrust structures, and copper channel combustors. Effort was terminated prior to completion of the repairs and conduct of a planned hot fire test program when it was found that the copper alloy walls of many of the thrust chamber's 24 combustors had been degraded in strength and ductility during the initial fabrication of the thrust chamber. The degradation is discussed and traced to a reaction between oxygen and/or oxides diffused into the copper alloy during fabrication processes and the hydrogen utilized as a brazing furnace atmosphere during the initial assembly operation on many of the combustors. The effects of the H<sub>2</sub>/O<sub>2</sub> reaction within the copper alloy are described.

Author

**N77-23194\*** Aerojet Liquid Rocket Co., Sacramento, Calif.  
**ADVANCED HIGH PRESSURE ENGINE STUDY FOR MIXED-MODE VEHICLE APPLICATIONS Final Report**  
W. P. Luscher and J. A. Mellish Jan. 1977 319 p refs  
(Contract NAS3-19727)  
(NASA-CR-135141) Avail: NTIS HC A14/MF A01  
CSCL 21H

High pressure liquid rocket engine design, performance, weight, envelope, and operational characteristics were evaluated for a variety of candidate engines for use in mixed-mode, single-stage-to-orbit applications. Propellant property and performance data were obtained for candidate Mode 1 fuels which included: RP-1, RJ-5, hydrazine, monomethyl-hydrazine, and methane. The common oxidizer was liquid oxygen. Oxygen, the candidate Mode 1 fuels, and hydrogen were evaluated as thrust chamber coolants. Oxygen, methane, and hydrogen were found to be the most viable cooling candidates. Water, lithium, and sodium-potassium were also evaluated as auxiliary coolant systems. Water proved to be the best of these, but the system was heavier than those systems which cooled with the engine propellants. Engine weight and envelope parametric data were established for candidate Mode 1, Mode 2, and dual-fuel engines. Delivered engine performance data were also calculated for all candidate Mode 1 and dual-fuel engines.

Author

**N77-21190\*** Hughes Research Labs., Malibu, Calif. Dept. of Ion Physics.  
**HIGH-POWER AND 2.5 kW ADVANCED-TECHNOLOGY ION THRUSTER Final Report, 27 May 1975 - 26 Sep. 1976**  
R. L. Poeschel Feb. 1977 135 p refs  
(Contract NAS3-19703)  
(NASA-CR-135163) Avail: NTIS HC A07/MF A01  
CSCL 21C

Investigations for improving ion thruster components in the 30 cm engineering model thruster (EMT) resulted in the demonstration of useful techniques for grid short removal and discharge chamber erosion monitoring, establishment of relationships between double ion production and thruster operating parameters, verification of satisfactory specifications on porous tungsten vaporizer material and barium impregnated porous tungsten inserts, demonstration of a new hollow cathode configuration, and specification of magnetic circuit requirements for reproducing desired magnetic mappings. The capacity of a 30 cm EMT to operate at higher beam voltages and currents (higher power) was determined. Operation at 2 A beam current and higher beam voltage is shown to be essentially equivalent to operation at 1.1 kV with regard to efficiency, lifetime and operating conditions. The only additional requirement is an improvement in high voltage insulation and propellant isolator capacity. Operation at minimum voltage and higher beam currents is shown to increase thruster discharge chamber erosion in proportion to beam current. Studies to find alternatives to molybdenum for manufacturing ion optics grids are also reported.

Author

**N77-24188\*** Rocketdyne, Canoga Park, Calif.  
**LASER-HEATED ROCKET THRUSTER Final Report, Jun. 1975 - Jun. 1976**  
J. M. Shoji 12 Apr. 1977 187 p refs  
(Contract NAS3-19728)  
(NASA-CR-135128; R76-104) Avail: NTIS HC A08/MF A01  
CSCL 21H

A space vehicle application using 5,000-kw input laser power was conceptually evaluated. A detailed design evaluation of a 10-kw experimental thruster including plasma size, chamber size, cooling, and performance analyses, was performed for 50 psia chamber pressure and using hydrogen as a propellant. The 10-kw hardware fabricated included a water cooled chamber, an uncooled copper chamber, an injector, igniters, and a thrust stand. A 10-kw optical train was designed.

Author

**N77-25241\*** Hughes Research Labs., Malibu, Calif. Ion Physics Dept.  
**FABRICATION AND VERIFICATION TESTING OF ETM 30 cm DIAMETER ION THRUSTERS Final Report, 14 Mar. 1974 - 15 Sep. 1976**  
C. Collett Apr. 1977 284 p refs  
(Contract NAS3-17803)  
(NASA-CR-135193) Avail: NTIS HC A13/MF A01  
CSCL 21C

Engineering model designs and acceptance tests are described for the 800 and 900 series 30 cm electron bombardment thrusters. Modifications to the test console for a 1000 hr verification test were made. The 10,000 hr endurance test of the S/N 701 thruster is described, and post test analysis results are included.

Author

**N77-23192\*** Hughes Research Labs., Malibu, Calif.  
**MODULARIZED ION THRUSTER Final Report, 3 Dec. 1975 - 13 Aug. 1976**  
J. Hyman, Jr. and C. R. Dulgeroff Nov. 1976 74 p refs  
(Contract NAS3-19691)  
(NASA-CR-134667) Avail: NTIS HC A04/MF A01  
CSCL 21C

A modularized ion thruster system was developed for space-propulsion applications. Separate discharge chamber modules (DCMs) were optimized for operation at the thrust levels of  $T = 0.5$  mlb and  $T = 2$  mlb to accommodate the extended thrust range. These optimizations included modifications in the

**N77-26221\*** Rocketdyne, Canoga Park, Calif.  
**ADVANCED THRUST CHAMBER TECHNOLOGY Final Report, Jan. 1974 - Aug. 1976**  
M. C. Yost, H. E. Marker, and P. C. Dannies 5 Jul. 1977 298 p refs  
(Contract NAS3-17825)  
(NASA-CR-135221; R76-116) Avail: Issuing Activity  
CSCL 21H

Base technology was developed for a high performance, high expansion area ratio nozzle, liquid hydrogen cooled thrust chamber assembly for a staged combustion cycle rocket engine.

The components required for high area ratio thrust chamber assembly (400:1), including injector, combustor, 175:1 area ratio intermediate nozzle and dump cooled, 400:1 nozzle were designed, fabricated and tested. Testing at area ratios of 175:1 and 400:1 was conducted at simulated altitude conditions utilizing a self pumping diffuser and a gaseous nitrogen ejector; tests at 8:1 area ratio were at sea level conditions. Diffuser/ejector operation was successful at 175:1 but inadequate start margin at 400:1 area ratio resulted in a non-pumping condition. Specific impulse performance was obtained for 8:1 and 175:1 area ratio testing and met analytical predictions. Projections to higher area ratios also met analytical predictions.

Author

**N77-31240\*** Colorado State Univ., Fort Collins. Dept. of Mechanical Engineering.

**MULTIPOLE GAS THRUSTER DESIGN Ph.D. Thesis**

Gerald C. Isaacson Jun. 1977 117 p refs  
(Grant NAG-3011)

(NASA-CR-135101) Avail: NTIS HC A06/MF A01 CSCL 21C

The development of a low field strength multipole thruster operating on both argon and xenon is described. Experimental results were obtained with a 15-cm diameter multipole thruster and are presented for a wide range of discharge-chamber configurations. Minimum discharge losses were 300-350 eV/ion for argon and 200-250 eV/ion for xenon. Ion beam flatness parameters in the plane of the accelerator grid ranged from 0.85 to 0.93 for both propellants. Thruster performance is correlated for a range of ion chamber sizes and operating conditions as well as propellant type and accelerator system open area. A 30-cm diameter ion source designed and built using the procedure and theory presented here-in is shown capable of low discharge losses and flat ion-beam profiles without optimization. This indicates that by using the low field strength multipole design, as well as general performance correlation information provided herein, it should be possible to rapidly translate initial performance specifications into easily fabricated, high performance prototypes.

Author

**A77-12678\*** Multipurpose insulation system for a radioisotope fueled Mini-Brayton Heat Source Assembly. P. Allar, W. Saylor, G. Schmidt, and D. Wein (General Electric Co., Space Div., Valley Forge, Pa.). In: Intersociety Energy Conversion Engineering Conference, 11th, State Line, Nev., September 12-17, 1976, Proceedings, Volume 1. (A77-12662 02-44) New York, American Institute of Chemical Engineers, 1976, p. 208-215. 6 refs. Contract No. NAS3-18541.

The Mini-Brayton Heat Source Assembly (HSA) consists of a radioisotope fueled heat source, a heat exchanger, a multifoil thermal insulation blanket, and a hermetically sealed housing. The thermal insulation blanket is a multilayer wrap of thin metal foil separated by a sparsely coated oxide. The objectives of the insulation blanket are related to the effective insulation of the HSA during operation, the transfer of the full thermal inventory to the housing when the primary coolant is not flowing, and the transfer of the full thermal inventory to the housing in the event of a flow stoppage of the primary coolant. A description is given of the approaches which have been developed to make it possible for the insulation blanket to meet these requirements.

G.R.

**A77-13000\*** A doubly charged ion model for ion thrusters. R. R. Peters, P. J. Wilbur (Colorado State University, Fort Collins, Colo.), and R. P. Vahrenkamp (Hughes Research Laboratories, Malibu, Calif.). *American Institute of Aeronautics and Astronautics, International Electric Propulsion Conference, Key Biscayne, Fla., Nov. 14-17, 1976, Paper 76-1010*. 12 p. 14 refs. Grant No. NGR-06-002-112; Contract No. NAS3-19703.

A theoretical equilibrium model of doubly charged ion production and loss processes in electron bombardment ion thrusters is presented. The model is shown to predict double ion density levels accurately for 15 and 30 cm diameter thrusters operating with

several different grid sets and at several different power levels. The model indicates the dominant mechanism of double ion production involves the singly charged ground state. This result is used to develop a much simpler model which, along with correlations of the average plasma properties, can be used to determine the double ion density in thrusters with acceptable accuracy.

(Author)

**A77-13012\*** Clearance of short circuited ion optics electrodes by capacitive discharge. R. L. Poeschel (Hughes Research Laboratories, Malibu, Calif.). *American Institute of Aeronautics and Astronautics, International Electric Propulsion Conference, Key Biscayne, Fla., Nov. 14-17, 1976, Paper 76-1031*. 13 p. Contract No. NAS3-19703.

The ion optics electrodes of low specific impulse (3000 sec) mercury electron bombardment ion thrusters are vulnerable to short circuits by virtue of their relatively small interelectrode spacing (0.5 mm). Metallic flakes from backspattered deposits are the most probable cause of such 'shorts' and 'typical' flakes have been simulated here using refractory wire that has a representative, but controllable, cross section. Shorting wires can be removed by capacitive discharge without significant damage to the electrodes. This paper describes an evaluation of 'short' removal versus electrode damage for several combinations of capacitor voltage, stored energy, and short circuit conditions.

(Author)

**A77-15088\*** Development of a 30-cm ion thruster thermal-vacuum power processor. B. G. Heaton (Hughes Research Laboratories, Malibu, Calif.). *American Institute of Aeronautics and Astronautics, International Electric Propulsion Conference, Key Biscayne, Fla., Nov. 14-17, 1976, Paper 76-991*. 7 p. 7 refs. Contract No. NAS3-17223.

The 30-cm Hg electron-bombardment ion thruster presently under development has reached engineering model status and is generally accepted as the prime propulsion thruster module to be used on the earliest solar electric propulsion missions. This paper presents the results of a related program to develop a transistorized 3-kW Thermal-Vacuum Breadboard (TVBB) Power Processor for this thruster. Emphasized in the paper are the implemented electrical and mechanical designs as well as the resultant system performance achieved over a range of test conditions. In addition, design modifications affording improved performance are identified and discussed.

(Author)

**A77-15091\*** Evolution and status of the 30-cm engineering model ion thruster. T. D. Masek, R. L. Poeschel, C. R. Collett, and D. E. Schnelker (Hughes Research Laboratories, Malibu, Calif.). *American Institute of Aeronautics and Astronautics, International Electric Propulsion Conference, Key Biscayne, Fla., Nov. 14-17, 1976, Paper 76-1006*. 16 p. 27 refs. Contracts No. NAS3-14140, No. NAS3-15523; No. NAS3-16928; No. NAS3-16949; No. NAS3-17803; No. NAS3-19703.

In the past five years the 30-cm ion thruster has developed from infancy to maturity through the joint efforts of the NASA Lewis Research Center (LeRC) and the Hughes Research Laboratories (HRL). The evolution of the 30-cm thruster from the 200-series design to the present 900-series is described. This evolution has included both breadboard and engineering model type thrusters. The evolution description includes functional requirements, design, performance, endurance test results, and major features. The major part of the discussion centers on Hughes-built hardware although NASA LeRC contributions are reflected in the designs.

(Author)

**A77-15092\*** High power operation of a 30-cm mercury bombardment ion thruster. R. L. Poeschel and R. P. Vahrenkamp (Hughes Research Laboratories, Malibu, Calif.). *American Institute of Aeronautics and Astronautics, International Electric Propulsion Conference, Key Biscayne, Fla., Nov. 14-17, 1976, Paper 76-1007*. 7 p. 7 refs. Contract No. NAS3-19703.

The nominal input power of a 30-cm mercury bombardment ion thruster is 2.5 kW. A representative 30-cm thruster has been operated at higher power levels by increasing either the ion beam voltage or current. Initial results indicate that higher voltage (high specific impulse) operation requires only minor modifications in thruster design. Higher current (low specific impulse) operation, on the other hand, requires improvements in the capabilities of the discharge chamber and ion optics assembly designs to meet lifetime and/or performance specifications. Experimental data is presented and considerations for high power operation (up to 10 kW) are discussed.

(Author)

**A77-15095 \* #** A 10,000 hour endurance test of a 700 series 30 cm engineering model thruster. C. R. Collett and R. L. Poeschel (Hughes Research Laboratories, Malibu, Calif.). *American Institute of Aeronautics and Astronautics, International Electric Propulsion Conference, Key Biscayne, Fla., Nov. 14-17, 1976, Paper 76-1019*, 9 p. Contracts No. NAS3-15523; No. NAS3-17803.

This paper describes a 10,000 hour test of the first engineering model of the 30-cm ion thruster which is expected to form the basis of future prime propulsion systems. This test demonstrated the lifetime capability of such critical components as cathodes, vaporizers, isolators, and optics. The results of the test are described including the conclusions derived from an extensive post-test analysis of the thruster. This test did identify a major life limiting problem - discharge chamber erosion. The modifications which have been incorporated in the 900 series 30-cm ion thrusters to minimize this problem are described.

(Author)

**A77-15100 \* #** Characteristics of a 30-cm thruster operated with small hole accelerator grid ion optics. R. P. Vahrenkamp (Hughes Research Laboratories, Malibu, Calif.). *American Institute of Aeronautics and Astronautics, International Electric Propulsion Conference, Key Biscayne, Fla., Nov. 14-17, 1976, Paper 76-1030*, 8 p. 12 refs. Contract No. NAS3-19703.

Small hole accelerator grid ion optical systems have been tested as a possible means of improving 30-cm ion thruster performance. The effects of small hole grids on the critical aspects of thruster operation including discharge chamber performance, doubly-charged ion concentration, effluent beam characteristics, and plasma properties have been evaluated. In general, small hole accelerator grids are beneficial in improving thruster performance while maintaining low double ion ratios. However, extremely small accelerator aperture diameters tend to degrade beam divergence characteristics. A quantitative discussion of these advantages and disadvantages of small hole accelerator grids, as well as resulting variations in thruster operation characteristics, is presented.

(Author)

**A77-15105 \* #** Performance and heat transfer characteristics of the laser-heated rocket - A future space transportation system. J. M. Shoji and V. R. Larson (Rockwell International Corp., Rocketdyne Div., Canoga Park, Calif.). *American Institute of Aeronautics and Astronautics, International Electric Propulsion Conference, Key Biscayne, Fla., Nov. 14-17, 1976, Paper 76-1044*, 34 p. Contract No. NAS3-19728.

The application of advanced liquid-bipropellant rocket engine analysis techniques has been utilized for prediction of the potential delivered performance and the design of thruster wall cooling schemes for laser-heated rocket thrusters. Delivered specific impulse values greater than 1000 lbf-sec/lbm are potentially achievable based on calculations for thrusters designed for 10-kW and 5000-kW laser beam power levels. A thruster wall-cooling technique utilizing a combination of regenerative cooling and a carbon-seeded hydrogen boundary layer is presented. The flowing carbon-seeded hydrogen boundary layer provides radiation absorption of the heat radiated from the high-temperature plasma. Also described is a forced convection thruster wall cooling design for an experimental test thruster.

(Author)

**A77-15106 \* #** Ion thruster design and analysis. S. Kami and D. E. Schnelker (Hughes Research Laboratories, Malibu, Calif.). *American Institute of Aeronautics and Astronautics, International Electric Propulsion Conference, Key Biscayne, Fla., Nov. 14-17, 1976, Paper 76-1048*, 11 p. 16 refs. Contracts No. NAS3-17803; No. NAS3-18917.

Questions concerning the mechanical design of a thruster are considered, taking into account differences in the design of an 8-cm and a 30-cm model. The components of a thruster include the thruster shell assembly, the ion extraction electrode assembly, the cathode isolator vaporizer assembly, the neutralizer isolator vaporizer assembly, ground screen and mask, and the main isolator vaporizer assembly. Attention is given to the materials used in thruster fabrication, the advanced manufacturing methods used, details of thruster performance, an evaluation of thruster life, structural and thermal design considerations, and questions of reliability and quality assurance.

G.R.

**A77-15107 \* #** Modularized ion thruster development. J. Hyman, Jr. and C. R. Duigeroff (Hughes Research Laboratories, Malibu, Calif.). *American Institute of Aeronautics and Astronautics, International Electric Propulsion Conference, Key Biscayne, Fla., Nov. 14-17, 1976, Paper 76-1049*, 8 p. 6 refs. Contract No. NAS3-19691.

A family of mercury ion thruster modules has been developed which extends the basic design of the Hughes-developed 1-mlb Engineering Model Thruster to accommodate the extended thrust range from 0.5 mlb to 4 mlb. In the subject program, separate Discharge Chamber Modules (DCM's) have been optimized for operation at nominal thrust levels  $T = 0.5$  mlb and 2 mlb; DCM optimization is continuing at thrust level  $T = 4$  mlb. Performance optimization required modification of the beam-extraction system and of discharge-chamber components; however, the cathodes and mechanical structure are unchanged from the Engineering Model design. Performance data on the optimized modules are given.

(Author)

**A77-15111 \* #** Development of an 8-cm engineering model thruster system. B. G. Herron, J. Hyman, Jr., and D. J. Hopper (Hughes Research Laboratories, Malibu, Calif.). *American Institute of Aeronautics and Astronautics, International Electric Propulsion Conference, Key Biscayne, Fla., Nov. 14-17, 1976, Paper 76-1058*, 12 p. 10 refs. Contract No. NAS3-18917.

Electric propulsion has been shown to offer major advantages over the techniques currently employed for the control of earth satellites. For a user to realize these advantages, however, requires the availability of a proven, operationally flight-ready propulsion system. Currently an Engineering Model of an 8-cm ion thruster propulsion system is under development. The system includes the thruster unit with its associated reservoir, thruster gimbal sub-system, and power processing unit. This paper describes the EM System with special emphasis on hardware design and system performance.

(Author)

**A77-15191 \* #** Arc discharge supply component protection circuitry. A. F. Ahrens and G. I. Cardwell (Hughes Aircraft Co., Space and Communications Group, El Segundo, Calif.). In: *Power Electronics Specialists Conference, Cleveland, Ohio, June 8-10, 1976, Record*. (A77-40951 19-33) New York, Institute of Electrical and Electronics Engineers, Inc., 1976, p. 326-333. Contract No. NAS3-17223.

In a mercury-bombardment ion engine, the discharge supply is a high-current low-voltage one that maintains an arc or discharge inside the engine. In a 30-cm engine the supply provides up to 45 volts at about 13 amperes and is referenced at approximately 1100 volts above ground. Due to the engine discharge characteristics, a very slow feedback control loop is required. A high-speed current limit must be used to protect the components in the power conditioner, r

pulse-width-modulated bridge inverter. A high-speed cycle-by-cycle current-limit circuit which allows the inverter to continue running in an overcurrent condition is used to protect it. The high-speed current sensing allows the inverter to be turned off each half cycle before the current in the primary of the inverter exceeds a safe level. This permits the inverter to continue to provide current into a discharge or a fault condition, until the feedback control system can actively control the current.

(Author)

**A77-41993 \*** # **Linear aerospike engine.** F. M. Kirby and A. Martinez (Rockwell International Corp., Rocketdyne Div., Canoga Park, Calif.). *American Institute of Aeronautics and Astronautics and Society of Automotive Engineers, Propulsion Conference, 13th, Orlando, Fla., July 11-13, 1977, AIAA Paper 77-968.* 20 p. Contract No. NAS3-20114.

A description is presented of a dual-fuel modular split-combustor linear aerospike engine concept. The considered engine represents an approach to an integrated engine for a reusable single-stage-to-orbit (SSTO) vehicle. The engine burns two fuels (hydrogen and a hydrocarbon) with oxygen in separate combustors. Combustion gases expand on a linear aerospike nozzle. An engine preliminary design is discussed. Attention is given to the evaluation process for selecting the optimum number of modules or divisions of the engine, aspects of cooling and power cycle balance, and details of engine operation.

G.R.

**A77-48732 \*** **Cell-level battery charge/discharge protection system.** R. L. Donovan and M. S. Imamura (Martin Marietta Aerospace, Denver, Colo.). In: *Intersociety Energy Conversion Engineering Conference, 12th, Washington, D.C., August 28-September 2, 1977, Proceedings. Volume 1.* (A77-48701 23-44) La Grange Park, Ill., American Nuclear Society, Inc., 1977, p. 302-310. Contract No. NAS3-19432.

The paper describes three design approaches to individual cell monitoring and control for sealed secondary battery cells. One technique involves a modular strap-on single cell protector which contains all the electronics required for monitoring cell voltage, responding to external commands, and forming a bypass circuit for the cell. A second technique, the multiplexed cell protector, uses common circuitry to monitor and control each cell in a battery pack. The third technique, the computerized cell protector, by replacing the hard-wired logic of the multiplexed cell protector with a microprocessor, achieves greatest control flexibility and inherent computational capability with a minimum parts count implementation.

M.L.

**A77-48733 \*** **Cycle life characteristics of sealed silver-zinc cell with inorganic separator.** J. W. Lear and M. S. Imamura (Martin Marietta Aerospace, Denver, Colo.). In: *Intersociety Energy Conversion Engineering Conference, 12th, Washington, D.C., August 28-September 2, 1977, Proceedings. Volume 1.* (A77-48701 23-44) La Grange Park, Ill., American Nuclear Society, Inc., 1977, p. 311-318. Contract No. NAS3-19432.

Two batteries containing 18 cells have been cycling in a simulated synchronous (24-hour) orbit for over a year at 40% depth of discharge at 22 C. One battery is under individual cell monitoring and control and the other battery is controlled at the battery level. The battery with individual cell monitoring and protection has performed over 350 cycles with no sign of failure. The battery without individual cell protection failed at 270 cycles from failure to remain above the specified minimum discharge voltage. A significant conclusion is that the sealed Ag-Zn cells manufactured with the inorganic separator material have demonstrated their capability to cycle at a fairly high depth of discharge and are worthy of consideration in short life synchronous orbit applications. (Author)

## 23 CHEMISTRY AND MATERIALS (GENERAL)

Includes biochemistry and organic chemistry.

**N77-15093\*** National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio.

### THE NATURE OF SURFACES AND THEIR INFLUENCE IN WEAR MECHANISMS

Donald H. Buckley [1976] 23 p refs To be presented at the Automotive Engineering Conf., Detroit, 28 Feb. - 4 Mar. 1977; sponsored by the Soc. of Automotive Engineers (NASA-TM-X-73516) Avail: NTIS HC A02/MF A01 CSCL 11G

The wear of materials is strongly dependent upon the nature of the solid surfaces in contact, their properties and the nature of their films. Oxide films, orientation, crystal transformations, adhesive binding, crystal structure, hardness, and the presence of alloying agents are all shown to affect one or more of the forms of wear. The three most common forms of wear, adhesive, abrasive, and corrosive, are discussed in terms of the way each is affected by various material properties. Results presented indicate how wear can be optimized by concern for properties of materials.

Author

**N77-25249\*** National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio.

### ION-BEAM TECHNOLOGY AND APPLICATIONS

Wayne R. Hudson, Ronald R. Robson, and James S. Sovey Washington May 1977 37 p refs (NASA-TM-X-3517: E-8910) Avail: NTIS HC A03/MF A01 CSCL 20L

Ion propulsion research and development yields a mature technology that is transferable to a wide range of nonpropulsive applications, including terrestrial and space manufacturing. A xenon ion source was used for an investigation into potential ion-beam applications. The results of cathode tests and discharge-chamber experiments are presented. A series of experiments encompassing a wide range of potential applications is discussed. Two types of processes, sputter deposition, and erosion were studied. Some of the potential applications are thin-film Teflon capacitor fabrication, lubrication applications, ion-beam cleaning and polishing, and surface texturing.

Author

**N77-29222\*** National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio.

### ELECTROCHEMICAL BEHAVIOR OF 0.2 TO 3 MOLAR FERROUS CHLORIDE-FERRIC CHLORIDE MIXTURES ON EDGE-ON PYROLYTIC GRAPHITE ROTATED DISK ELECTRODES

Riley O. Miller Jul. 1977 12 p refs (Contract E(49-28)-1022)

(NASA-TM-X-73716: ERDA/NASA-5022-77/2; E-9199) Avail: NTIS HC A02/MF A01 CSCL 07C

Potentiostatic determinations in various mixtures of  $\text{FeCl}_2$ - $\text{FeCl}_3$  with excess  $\text{HCl}$  show rest potentials that are 0.1 V less electropositive than the theoretical values from the formulated ratios of  $\text{Fe}^{II}$  to  $\text{Fe}^{III}$  (probably as a result of complexing). The standard rate constant  $k_s$  ranges between 0.0001 and 0.0005 cm/sec. Tafel slopes  $b$  of roughly 0.12 V per decade indicate single-electron exchange kinetics. No significant trend in either  $b$  or  $k_s$  was attributed to mixture composition. The higher  $k_s$  values occurred with and edge-on pyrolytic graphite that had undergone a permanent surface change.

Author

**N77-32242\*** National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio.

### A HIGH PRESSURE MODULATED MOLECULAR BEAM MASS SPECTROMETRIC SAMPLING SYSTEM

Carl A. Stearns, Fred J. Kohl, George C. Fryburg, and Robert A. Miller Jul. 1977 57 p refs (NASA-TM-73720; E-9270) Avail: NTIS HC A04/MF A01 CSCL 07D

The current state of understanding of free-jet high pressure sampling is critically reviewed and modifications of certain theoretical and empirical considerations are presented. A high pressure, free-jet expansion, modulated molecular beam, mass spectrometric sampling apparatus was constructed and this apparatus is described in detail. Experimental studies have demonstrated that the apparatus can be used to sample high temperature systems at pressures up to one atmosphere. Condensible high temperature gaseous species have been routinely sampled and the mass spectrometric detector has provided direct identification of sampled species. System sensitivity is better than one tenth of a part per billion. Experimental results obtained with argon and nitrogen beams are presented and compared to theoretical predictions. These results and the respective comparison are taken to indicate acceptable performance of the sampling apparatus. Results are also given for two groups of experiments related to hot corrosion studies. The formation of gaseous sodium sulfate in doped methane-oxygen flames was characterized and the oxidative vaporization of metals was studied in an atmospheric pressure flowing gas system to which gaseous salt partial pressures were added.

Author

**N77-32244\*** National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio.

### CATALYTIC TRIMERIZATION OF AROMATIC NITRILES AND TRIARYL-S-TRIAZINE RING CROSS-LINKED HIGH TEMPERATURE RESISTANT POLYMERS AND COPOLYMERS MADE THEREBY Patent Application

Li-Chen Hsu, inventor (to NASA) Filed 12 May 1977 45 p (NASA-Case-LEW-12053-2; US-Patent-Appl-SN-796283) Avail: NTIS HC A03/MF A01 CSCL 07C

Triazine compounds and cross-linked polymer compositions are made by heating aromatic nitriles to a temperature in the range of from about 100 C to about 700 C, and preferably in the range of from about 200 C to about 350 C in the presence of a catalyst or mixture of catalysts selected from one or more of the following groups: (A) organic sulfonic and sulfonic acids, (B) organic phosphonic and phosphonic acids, and (C) metallic acetylacetonates, at a pressure in the range of from about atmospheric pressure to about 10,000 psi, and preferably in the range of from about 200 psi to about 750 psi. Aromatic nitrile-modified (terminated and/or appended) imide, benzimidazole, imidazopyrrolone, quinoxaline, and other condensation type prepolymers or their prepolymers are made which are trimerized with or without a filler by the aforementioned catalytic trimerization process into triaryl-s-triazine ring containing cross-linked polymeric or copolymeric products useful in applications requiring high thermal-oxidative stability and high performance structural properties at elevated temperatures.

NASA

**A77-44569 \*** Summary of NASA research on thermal-barrier coatings. F. S. Stepka, C. H. Liebert, and S. Stecura (NASA, Lewis Research Center, Cleveland, Ohio). *Society of Automotive Engineers, International Automotive Engineering Congress and Exposition, Detroit, Mich., Feb. 28-Mar. 4, 1977, Paper. 27 p. 9 refs.*

This paper summarizes the work conducted at the NASA Lewis Research Center to evolve and evaluate a two-layer, thermal-barrier coating system. A durable, two-layer, plasma-sprayed coating consisting of a ceramic layer over a metallic layer was developed that has the potential of insulating hot engine parts and thereby reducing metal temperatures and coolant flow requirements and/or permitting use of less costly and complex cooling configurations and materials. The investigations evaluated the reflective and insulative capability, microstructure, and durability of several coating materials on flat

metal specimens, a combustor liner, and turbine vanes and blades. In addition, the effect on the aerodynamic performance of a coated turbine vane was measured. The tests were conducted in furnaces, cascades, hot-gas rigs, an engine combustor, and a research turbojet engine. Included also are summaries of current research related to the coating and potential applications for the coating. (Author)



## 24 COMPOSITE MATERIALS

Includes laminates.

**N77-10160\*** National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio.

### NITRILE-CROSSLINKED POLYPHENYL-QUINOXALINE/GRAPHITE FIBER COMPOSITES

William B. Alston 1976 20 p refs Presented at the 8th Natl. Symp. and Tech. Conf. of the Soc. for the Advan. of Mater. and Process Eng., Seattle, 12-14 Oct. 1976 Prepared in cooperation with Army Air Mobility R and D Lab., Cleveland, Ohio

(NASA-TM-X-73456; E-8815) Avail: NTIS HC A02/MF A01 CSCL 11D

Studies were performed to reduce the 600 F thermoplasticity of polyphenylquinoxaline (PPQ) matrix resins by introducing crosslinking by the reaction of terminal nitrile groups. Seven solvents and solvent mixtures were studied as the crosslinking catalysts and used to fabricate crosslinked PPQ/HMS graphite fiber composites. The room temperature and 600 F composite mechanical properties after short time and prolonged 600 F air exposure and the 600 F composite weight loss were determined and compared to those properties of high molecular weight, linear PPQ/HMS graphite fiber composites. Author

**N77-11118\*** National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio.

### EFFECT OF FIBER DIAMETER AND MATRIX ALLOYS ON IMPACT-RESISTANT BORON/ALUMINUM COMPOSITES

David L. McDanel and Robert A. Signorelli Washington Nov. 1976 38 p refs

(NASA-TN-D-8204; E-8648) Avail: NTIS HC A03/MF A01 CSCL 11D

Efforts to improve the impact resistance of B/Al are reviewed and analyzed. Nonstandard thin-sheet Charpy and Izod impact tests and standard full-size Charpy impact tests were conducted on composites containing unidirectional 0.10mm, 0.14mm, and 0.20mm diameter boron fibers in 1100, 2024, 5052, and 6061 Al matrices. Impact failure modes of B/Al are proposed in an attempt to describe the mechanisms involved and to provide insight for maximizing impact resistance. The impact strength of B/Al was significantly increased by proper selection of materials and processing. The use of a ductile matrix and large diameter boron fibers gave the highest impact strengths. This combination resulted in improved energy absorption through matrix shear deformation and multiple fiber breakage. Author

**N77-16097\*** National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio.

### SUMMARY OF NASA RESEARCH ON THERMAL-BARRIER COATINGS

Francis S. Stepka, Curt H. Liebert, and Stephan Stecura [1977] 27 p refs Proposed for presentation at the Automotive Eng. Conf., Detroit, 28 Feb.-4 Mar. 1977. Sponsored by the SAF (NASA-TM-X-73584) Avail: NTIS HC A03/MF A01 CSCL 11D

A durable, two-layer, plasma-sprayed coating consisting of a ceramic layer over a metallic layer was developed that has the potential of insulating hot engine parts and thereby reducing metal temperatures and coolant flow requirements and/or permitting use of less costly and complex cooling configurations and materials. The investigations evaluated the reflective and insulative capability, microstructure, and durability of several coating materials on flat metal specimens, a combustor liner, and turbine vanes and blades. In addition, the effect on the aerodynamic performance of a coated turbine vane was measured. The tests were conducted in furnaces, cascades, hot-gas rigs, an engine combustor, and a research turbojet engine. Summaries of current research related to the coating and potential applications for the coating are included. Author

**DATA SUMMARY:** Fatigue tests of uncoated and zirconia thermal-barrier coated turbine vanes and combustor liners. variables include cycles-to-failure; coating thickness, leading edge wall metal temperature, coolant-to-gas flow rate, maximum liner temperature, flame radiation, average exhaust gas temperature. 6 figures and 1 table include numeric data.

**N77-16115\*** National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio.

### OXIDATION BEHAVIOR OF NICKEL-CHROMIUM-ALUMINUM-YTTRIUM - MAGNESIUM OXIDE AND NICKEL-CHROMIUM-ALUMINUM-YTTRIUM - ZIRCONATE TYPE OF CERMETS

Isidor Zaplatynsky Washington Dec. 1976 18 p refs (NASA-TM-X-3466; E-8834) Avail: NTIS HC A02/MF A01 CSCL 11D

The 1100 and 1200 C cyclic oxidation resistance of dense Ni-Cr-Al-Y - MgO, Ni-Cr-Al-Y - CaZrO<sub>3</sub>, Ni-Cr-Al-Y - SrZrO<sub>3</sub>, Ni-Cr-Al-Y - MgZrO<sub>3</sub> cermets and a 70 percent dense Ni-Cr-Al-Y developmental material was determined. The cermets contained 60 and 50 volume percent of Ni-Cr-Al-Y which formed a matrix with the oxide particles imbedded in it. The cermets containing MgO were superior to cermets based on zirconates and to the porous Ni-Cr-Al-Y material. Author

**DATA SUMMARY:** Cyclic oxidation tests of four cermet systems; variables include simple oxide content, element content, oxidation temperature, specific weight change, number of cycles, and X-ray diffraction pattern intensities; 2 figures and 3 tables include numeric data.

**N77-17164\*** National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio.

### ELASTIC PROPERTIES AND FRACTURE STRENGTH OF QUASI-ISOTROPIC GRAPHITE/EPOXY COMPOSITES

T. L. Sullivan 1977 16 p refs Presented at Conf. on Composites and Advanced Materials, Cocoa Beach, Fla., 17-19 Jan. 1977, sponsored by Am. Ceramic Soc.

(NASA-TM-X-73592; E-9060) Avail: NTIS HC A02/MF A01 CSCL 11D

The layups of the studied laminates are (0, + or - 60) sub s, (0, + or - 45, 90) sub s, (0, + or - 30, + or - 60, 90) sub s (0, + or - 22 1/2, + or - 45, + or - 67 1/2, 90) sub s. The properties determined were tensile modulus, Poisson's ratio, bending stiffness, fracture strength and fracture strain. Measured properties and properties predicted using laminate theory were found to be in reasonable agreement. Reasons for data scatter were determined. Author

**DATA SUMMARY:** Measured and predicted elastic properties in tension and bending of laminates made from high modulus graphite fiber and epoxy plys; the variables include ply properties, elastic constants, tensile modulus, Poisson's ratio, axial stress, strain rate, load angle, ply alignment, fracture strength, and fracture strain; 9 figures and 2 tables include numeric data.

**N77-17167\*** National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio.

### PRELIMINARY EVALUATION OF FIBER COMPOSITE REINFORCEMENT OF TRUCK FRAME RAILS

James R. Faddoul 1977 22 p Presented at the Congr. and Exposition sponsored by the Soc. of Automotive Engineers, Detroit, 28 Feb. - 4 Mar. 1977

(NASA-TM-X-73582; E-9C44) Avail: NTIS HC A02/MF A01 CSCL 11D

The use of graphite fiber/resin matrix composite to effectively reinforce a standard steel truck frame rail is studied. A preliminary design was made and it was determined that the reinforcement weight could be reduced by a factor of 10 when compared to a steel reinforcement. A section of a 1/3 scale reinforced rail was fabricated to demonstrate low cost manufacturing techniques. The scale rail section was then tested and increased stiffness was confirmed. No evidence of composite fatigue was found after 500,000 cycles to a fiber stress of 34,000 psi. The

test specimen failed in bending in a static test at a load 50 percent greater than that predicted for a non-reinforced rail. Author

**DATA SUMMARY:** Static deflection, cyclic stress fatigue, and bending test were performed on 1/3 scale steel rail sections reinforced by graphite/resin caps for increased stiffness and buckling load capability; the variables include frame rail design parameters, reinforcement weight, graphite composite thickness, fiber modulus, moment of inertia, load deflection, and crack location and propagation; 6 figures and two tables include numeric data.

**N77-18218\*** National Aeronautics and Space Administration, Lewis Research Center, Cleveland, Ohio

**MICROSTRUCTURAL AND WEAR PROPERTIES OF SPUTTERED CARBIDES AND SILICIDES**

T Spalvins 1977 11 p refs To be presented at the Intern. Conf. on Wear of Materials, St. Louis, 25-27 Apr. 1977 (NASA-TM-X-73536; E-8842) Avail. NTIS HC A02/MF A01 CSCL 11D

Sputtered Cr<sub>3</sub>C<sub>2</sub>, Cr<sub>3</sub>Si<sub>2</sub>, and MoSi<sub>2</sub> wear-resistant films (0.05 to 3.5 microns thick) were deposited on metal and glass surfaces. Electron transmission electron diffraction, and scanning electron microscopy were used to determine the microstructural appearance. Strong adherence was obtained with these sputtered films. Internal stresses and defect crystallographic growth structures of various configurations within the film have progressively more undesirable effects for film thicknesses greater than 1.5 microns. Sliding contact and rolling element bearing tests were performed with these sputtered films. Bearings sputtered with a duplex coating (0.1-micron-thick undercoating of Cr<sub>3</sub>Si<sub>2</sub> and subsequently 0.6-micron coating of MoSi<sub>2</sub>) produced marked improvement over straight MoS<sub>2</sub> films. Author

**DATA SUMMARY:** Endurance lives of 440 C stainless steel, ball bearings with sputtered MoS<sub>2</sub> films on races and cage, with and without a Cr<sub>3</sub>Si<sub>2</sub> underlayer; variable coefficient of friction, applied load, and test time; 2 figures include numeric data.

**N77-18219\*** National Aeronautics and Space Administration, Lewis Research Center, Cleveland, Ohio

**HYBRID COMPOSITES, STATE-OF-THE-ART REVIEW: ANALYSIS, DESIGN, APPLICATION AND FABRICATION**

C. C. Chamis and R. F. Lark 1977 54 p refs Presented at the 18th Ann. Structural Dynamics and Materials Conf., San Diego, Calif., 21-25 Mar. 1977; cosponsored by the Am. Inst. of Aeron. and Astronautics, the Am. Soc. of Mech. Engrs., and the Soc. of Automotive Engrs. (NASA-TM-X-73545; E-8980) Avail. NTIS HC A04/MF A01 CSCL 11D

The areas of constituents and types of hybrids, analytical methods, design methods, applications, and fabrication procedures are discussed. The review summarizes significant contributions in each area and points out areas for further research. The description of each significant contribution is supplemented with pertinent illustrations and references. Author

**DATA SUMMARY:** Hybrid fiber composite laminates for structural application; the variables include stress-strain diagrams, fiber volume ratio, density, modulus of elasticity, Poisson's ratio, ply thickness, laminate composition, fiber compatibility, tensile strength, fracture toughness, temperature effects, and fabrication costs; 31 figures and 9 tables

**N77-19170\*** National Aeronautics and Space Administration, Lewis Research Center, Cleveland, Ohio

**LEADING EDGE PROTECTION FOR COMPOSITE BLADES**

Patent  
James W. Brantley (GE Co., Cincinnati) and Thomas P. Irwin, inventors (to NASA) (GE Co., Cincinnati) Issued 8 Feb 1977 6 p Filed 17 Jul. 1975 Sponsored by NASA (NASA-Case-LEW-12550-1; US-Patent-4,006,999; US-Patent-Appl-SN-596905; US-Patent-Class-416-224; US-Patent-Class-416-230) Avail. US Patent Office CSCL 11D

A laminated filament composite structure, such as an airfoil for use in an environment in which it is subjected to both foreign object impact and bending is provided with improved leading edge protection. At least one fine wire mesh layer is partially bonded within the composite structure along its neutral bending axis. A portion of the wire mesh layer extends beyond the neutral bending axis and partially around the leading edge where it is bonded to the outer periphery of the primary composite structure. The wire mesh is clad with a metal such as nickel to provide an improved leading edge protective device which is firmly anchored within the composite structure. Also described is a novel method of constructing a composite airfoil so as to further minimize the possibility of losing the leading edge protective device due to delamination caused by impact and bending.

Official Gazette of the U.S. Patent Office

**DATA SUMMARY:** No numeric data are presented.

**N77-19171\*** National Aeronautics and Space Administration, Lewis Research Center, Cleveland, Ohio

**METHOD OF MAKING REINFORCED COMPOSITE STRUCTURE Patent**

Lae C. McCandless (General Technologies Corp., Reston, Va.) and Glenn E. Weber, inventors (to NASA) (General Technologies Corp., Reston, Va.) Issued 2 Nov 1976 6 p Filed 19 Apr. 1974 Supersedes N76-16181 (14 - 07, p 0817) Sponsored by NASA

(NASA-Case-LEW-12619-1; US-Patent-3,989,602)

US-Patent-Appl-SN-452424; US-Patent-Class-204-9.

US-Patent-Class-29-527 2; US-Patent-Class-204-16;

US-Patent-Class-204-40) Avail. US Patent Office CSCL 11D

High strength nickel matrix structures are achieved by using reinforcing filament windings. Metal matrix materials were electro-formed on and between the windings to form each new layer of the composite structure.

Official Gazette of the U.S. Patent Office

**DATA SUMMARY:** Reinforcing stainless steel wires in nickel matrices for cylindrical windings; the variables include wire thickness, layers, nickel matrix materials, tensile strength, heat treatment, electroplating, and machining; 7 figures and 3 tables.

**N77-20168\*** National Aeronautics and Space Administration, Lewis Research Center, Cleveland, Ohio

**FRICTION AND WEAR BEHAVIOR OF GRAPHITE FIBER REINFORCED POLYIMIDE COMPOSITES**

Robert L. Fusaro and Harold E. Sliney 1977 22 p refs Proposed for presentation at the Ann. Lubrication Meeting of the Am. Soc. of Lubrication Engr., Montreal, 9-12 May 1977

(NASA-TM-X-73565; E-9012) Avail. NTIS HC A02/MF A01 CSCL 11D

The friction and wear rate characteristics of 50/50 (weight percent) graphite fiber polyimide composites were studied by sliding metallic hemispherically tipped riders against disks made from the composites. Two different polyimides and two different graphite fibers were evaluated. Also studied were such variables as the effect of moisture in an air atmosphere; the effect of temperature; and the effect of different sliding speeds. In general, wear to the metallic riders was negligible, and composite wear increased at a constant rate as a function of number of sliding cycles. Author

**N77-20169\*** National Aeronautics and Space Administration, Lewis Research Center, Cleveland, Ohio

**CONCEPTS FOR THE DEVELOPMENT OF LIGHT-WEIGHT COMPOSITE STRUCTURES FOR ROTOR BURST CONTAINMENT**

Arthur G. Holmes 1977 34 p refs Proposed for presentation at the NASA Workshop on an Assessment of Technol. for Turbojet Engine Rotor Failures, Cambridge, Mass., 29-31 Mar. 1977 (NASA-TM-X-73633; E-9129) Avail. NTIS HC A03/MF A01 CSCL 11D

A set of hypotheses is established as to what variables might control the design of a weight-efficient protective device. A particular experiment for evaluating the hypotheses and materials was designed. The design and methods for the analysis of results are described. Author

**N77-21193\*** National Aeronautics and Space Administration, Lewis Research Center, Cleveland, Ohio.

**RESIDUAL STRESSES IN BORON/TUNGSTEN AND BORON/CARBON FIBERS**

D. R. Behrendt 1977 9 p refs Presented at 106th Ann. Meeting of the Metallurgical Soc. of the Am. Inst. of Mining, Metallurgical and Petroleum Engr., Atlanta, 6-10 Mar. 1977 (NASA-TM-X-73616) Avail: NTIS HC A02/MF A01 CSCL 11D

By measuring the change in fracture stress of 203 micrometer diameter fibers of boron on tungsten (B/W) as a function of fiber diameter as reduced by chemical etching, it is shown that the flaws which limit B/W fiber strength are located at the surface and in the tungsten boride core. After etching to a diameter of 188 micrometers in virtually all fiber fractures were caused by core flaws, the average strength being 4.50 GN/sq m. If both the surface and core flaws are removed, the fracture strength, limited by flaws in the boron itself, is approximately 6.89 GN/sq m. This was measured on B/W fibers which were split longitudinally and had their cores removed by chemical etching. The longitudinal residual stress distribution was determined for 102 micrometer diameter B/W and B/C fibers.

Author

**N77-23207\*** National Aeronautics and Space Administration, Lewis Research Center, Cleveland, Ohio.

**TECHNIQUES FOR INCREASING BORON FIBER FRACTURE STRAIN**

J. A. DiCarlo 1977 31 p refs Presented at 106th Ann. Meeting of the Am. Inst. of Mining, Metallurgical, and Petroleum Engr., Atlanta, Ga., 6-10 Mar. 1977 (NASA-TM-X-73627, E-9119) Avail: NTIS HC A03/MF A01 CSCL 11D

Improvement in the strain-to-failure of CVD boron fibers is shown possible by contracting the tungsten boride core region and its inherent flaws. The results of three methods are presented in which etching and thermal processing techniques were employed to achieve core flow contraction by internal stresses available in the boron sheath. After commercially and treatment induced surface flaws were removed from 203 micrometers (8 mil) fibers, the core flow was observed to be essentially the only source of fiber fracture. Thus, fiber strain-to-failure was found to improve by an amount equal to the treatment induced contraction on the core flow. Commercial feasibility considerations suggest as the most cost effective technique that method in which as-produced fibers are given a rapid heat treatment above 700 C. Preliminary results concerning the contraction kinetics and fracture behavior observed are presented and discussed both for high vacuum and argon gas heat treatment environments.

Author

**N77-23208\*** National Aeronautics and Space Administration, Lewis Research Center, Cleveland, Ohio.

**TEN DEG OFF-AXIS TEST FOR SHEAR PROPERTIES IN FIBER COMPOSITES**

C. C. Chamis and J. H. Sinclair 1977 14 p refs Presented at Spring Meeting of the Soc. for Experimental Stress Analysis, Dallas, Tex., 15-20 May 1977 (NASA-TM-X-73550, E-8577) Avail: NTIS HC A02/MF A01 CSCL 11D

A combined theoretical and experimental investigation was conducted to assess the suitability of the 10 deg off-axis tensile test specimen for the intralaminar shear characterization of unidirectional composites. Composite mechanics, a combined-stress failure criterion, and a finite variation across the specimen width and the relative stress and strain magnitudes at the 10 deg plane. Strain gages were used to measure the strain variation across the specimen width at specimen midlength and near the

end tabs. Specimens from Mod-I/epoxy, T-300/epoxy, and S-glass/epoxy were used in the experimental program. It was found that the 10 deg off-axis tensile test specimen is suitable for intralaminar shear characterization, and it is recommended that it should be considered as a possible standard test specimen for such a characterization. Author

**N77-23209\*** National Aeronautics and Space Administration, Lewis Research Center, Cleveland, Ohio.

**THERMAL DEGRADATION OF THE TENSILE STRENGTH OF UNIDIRECTIONAL BORON/ALUMINUM COMPOSITES**

H. H. Grimes, R. A. Lad, and J. E. Maisel 1977 17 p refs Presented at Spring Meeting of the Metals Soc. of the Am. Inst. of Mining, Metallurgical and Petroleum Engr., Atlanta, Ga., 6-11 Mar. 1977

(NASA-TM-X-73614, E-9097) Avail: NTIS HC A02/MF A01 CSCL 11D

The variation of ultimate tensile strength with thermal treatment of B-Al composite materials and of boron fibers chemically removed from these composites in an attempt to determine the mechanism of the resulting strength degradation was studied. Findings indicate that thermally cycling B-Al represents a more severe condition than equivalent time at temperature. Degradation of composite tensile strength from about 1.3 GN/m squared to as low as 0.34 GN/m squared was observed after 3,000 cycles to 420 C for 203 micrometers B-1100 Al composite. In general, the 1100 Al matrix composites degraded somewhat more than the 6061 matrix material studied. Measurement of fiber strengths confirmed a composite strength loss due to the degradation of fiber strength. Microscopy indicated a highly flawed fiber surface.

Author

**N77-23210\*** National Aeronautics and Space Administration, Lewis Research Center, Cleveland, Ohio.

**ULTRASONIC EVALUATION OF THE STRENGTH OF UNIDIRECTIONAL GRAPHITE-POLYIMIDE COMPOSITES**

A. Vary and K. J. Bowles 1977 27 p refs Presented at 11th Symp. on Nondestructive Evaluation, San Antonio, 20-22 Apr. 1977; sponsored by Am. Soc. for Nondestructive Testing and Southwest Res. Inst.

(NASA-TM-X-73646, E-9153) Avail: NTIS HC A03/MF A01 CSCL 11D

An acoustic-ultrasonic method is described that was successful in ranking unidirectional graphite-polyimide composite specimens according to variations in interlaminar shear strength. Using this method, a quantity termed the stress wave factor was determined. It was found that this factor increases directly with interlaminar shear strength. The key variables in this investigation were composite density, fiber weight fraction, and void content. The stress wave factor and other ultrasonic factors that were studied were found to provide a powerful means for nondestructive evaluation of mechanical strength properties.

Author

**N77-27188\*** National Aeronautics and Space Administration, Lewis Research Center, Cleveland, Ohio.

**HYBRID COMPOSITE LAMINATE STRUCTURES Patent**

Christos C. Chamis and Raymond F. Lark, inventors (to NASA) Issued 14 Jun. 1977 12 p. Filed 24 Sep. 1975 Supersedes N75-32180 (13 - 23, p 2886)

(NASA-Case-LEW-12118-1; US-Patent-4,029,838;

US-Patent-Appl-SN-616332; US-Patent-Class-428-301;

US-Patent-Class-428-328; US-Patent-Class-428-368;

US-Patent-Class-428-418; US-Patent-Class-428-457;

US-Patent-Class-428-902; US-Patent-Class-428-911) Avail: US Patent Office CSCL 11D

An invention which relates to laminate structures and specifically to essentially anisotropic fiber composite laminates is described. Metal foils are selectively disposed within the laminate to produce increased resistance to high velocity impact, fracture, surface erosion, and other stresses within the laminate.

Official Gazette of the U.S. Patent Office

**N77-29226\*** # National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio.

**X-RAY PHOTOELECTRON SPECTROSCOPY STUDY OF**

**RADIOFREQUENCY SPUTTERED CHROMIUM BROMIDE, MOLYBDENUM DISULFIDE, AND MOLYBDENUM DISULFIDE COATINGS AND THEIR FRICTION PROPERTIES**

Donald R. Wheeler and William A. Brainard Washington Aug. 1977 21 p refs  
(NASA-TN-D-8482; E-9059) Avail: NTIS HC A02/MF A01 CSCL 11D

Radiofrequency sputtered coatings of CRB2, MOSI2, and MOS2 were examined by X-ray photoelectron spectroscopy. The effects of sputtering target history, deposition time, RF power level, and substrate bias on film composition were studied. Friction tests were run on RF sputtered surfaces of 440-C steel to correlate XPS data with lubricating properties. Significant deviations from stoichiometry and high oxide levels for all three compounds were related to target outgassing. The effect of biasing on these two factors depended on the compound. Improved stoichiometry correlated well with good friction and wear properties. Author

**N77-32248\*** # National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio.

**EFFECT OF PROCESSING PARAMETERS ON AUTOCLAVED PMR POLYIMIDE COMPOSITES**

Raymond D. Vannucci Oct. 1977 16 p refs Presented at 9th Natl. Tech. Conv., Atlanta, 4-8 Oct. 1977; sponsored by Atlanta Chapter of the Soc. for Adv. of Mater. and Process Eng.

(NASA-TM-73701; E-9240) Avail: NTIS HC A02/MF A01 CSCL 11D

A study was conducted to determine the effect of processing parameters on the processability and properties of autoclaved fiber reinforced PMR polyimide composites. Composites were fabricated from commercially available graphite fabric and glass fabric PMR polyimide prepreg materials. Process parameters investigated included degree of resin advancement, heating rate, and cure pressure. Composites were inspected for porosity by ultrasonic C scan and photomicrographic examination. Processing characteristics for each set of process parameters and the effect of process parameters on composite mechanical properties at room temperature and 600 F are described. Author

**N77-32249\*** # National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio.

**BEARING MATERIAL Patent Application**

Harold E. Sliney, inventor (to NASA) Filed 31 Jan. 1977 28 p

(NASA-Case-LEW-11930-3; US-Patent-Appl-SN-764245) Avail: NTIS HC A03/MF A01 CSCL 11D

A composite material is reported that provides low friction surfaces for materials in rolling or sliding contact and is self-lubricating and oxidation resistant up to and in excess of about 930 C. The composite is comprised of a metal component which lends strength and elasticity to the structure, a fluoride salt component which provides lubrication, and a glass component which not only provides oxidation protection to the metal but may also enhance the lubrication qualities of the composite. NASA

**N77-33265\*** # National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio.

**RECENT ADVANCES IN LIGHTWEIGHT, FILAMENT-WOUND COMPOSITE PRESSURE VESSEL TECHNOLOGY**

R. F. Lark 22 Sep. 1977 34 p refs Presented at the 1977 Energy Conf., Houston, Tex., 18-23 Sep. 1977; sponsored by ASME

(NASA-TM-73699; E-9239) Avail: NTIS HC A03/MF A01 CSCL 11D

A review of recent advances is presented for lightweight, high performance composite pressure vessel technology that covers the areas of design concepts, fabrication procedures, applications, and performance of vessels subjected to single cycle

burst and cyclic fatigue loading. Filament wound fiber/epoxy composite vessels were made from S glass, graphite, and Kevlar 49 fibers and were equipped with both structural and nonstructural liners. Pressure vessels structural efficiencies were attained which represented weight savings, using different liners, of 40 to 60 percent over all titanium pressure vessels. Significant findings in each area are summarized. Author

**A77-13033\*** # NASA electric propulsion program. W. R. Hudson (NASA, Washington, D.C.) and R. C. Finke (NASA, Lewis Research Center, Electric Propulsion Branch, Cleveland, Ohio). *American Institute of Aeronautics and Astronautics, International Electric Propulsion Conference, Key Biscayne, Fla., Nov. 14-17, 1976, Paper 76-1068*, 10 p, 18 refs.

Major portions of the NASA electric propulsion technology program have attained the level of maturity required to achieve near-term technology readiness for flight missions for primary and auxiliary propulsion application. Advanced electric propulsion program elements addressing less immediate requirements are in more exploratory stages. This paper will discuss the NASA electric propulsion technology program including planetary and earth orbit raising applications, attitude control and stationkeeping of geosynchronous satellites, and the research support program. Objectives, requirements, and hardware status are presented for each program. (Author)

**A77-13034\*** # High reliability cathode heaters for ion thrusters. L. A. Mueller (NASA, Lewis Research Center, Cleveland, Ohio). *American Institute of Aeronautics and Astronautics, International Electric Propulsion Conference, Key Biscayne, Fla., Nov. 14-17, 1976, Paper 76-1071*, 11 p.

A number of space missions have been proposed which will utilize 30-cm mercury bombardment ion thrusters and also will require a large number of thruster restarts. A test program was carried out to determine thermal cycle life of several different cathode heater designs. Plasma/flame sprayed heaters and swaged type heaters were tested. Four of the five plasma/flame sprayed heaters tested failed in a comparatively short time. Four tantalum swaged heaters that were brazed to the tantalum cathode tube were successfully tested and met the goals that were set at the start of the test. (Author)

**A77-21619\*** Elastic properties and fracture strength of quasi-isotropic graphite/epoxy composites. T. L. Sullivan (NASA, Lewis Research Center, Cleveland, Ohio). *American Ceramic Society, Conference on Composites and Advanced Materials, Cocoa Beach, Fla., Jan. 17-19, 1977, Paper*, 15 p.

A research program is described which was devised to determine experimentally the elastic properties in tension and bending of quasi-isotropic laminates made from high-modulus graphite fiber and epoxy. Four laminate configurations were investigated, and determinations were made of the tensile modulus, Poisson's ratio, bending stiffness, fracture strength, and fracture strain. The measured properties are compared with those predicted by laminate theory, reasons for scatter in the experimental data are discussed, and the effect of fiber misalignment on predicted elastic tensile properties is examined. The results strongly suggest that fiber misalignment in combination with variation in fiber volume content is responsible for the scatter in both elastic constants and fracture strength. F.G.M. DATA SUMMARY: Diverse data are presented; variables include bending stiffness, longitudinal tensile modulus, transverse tensile modulus, shear modulus, shear strength, Poisson's ratio, longitudinal thermal coefficient of expansion, transverse thermal coefficient of expansion, longitudinal tensile strength, transverse compressive strength.

**A77-25761 \* #** Hybrid composites - State-of-the-art review: Analysis, design, application and fabrication. C. C. Chamis and R. F. Lark (NASA, Lewis Research Center, Cleveland, Ohio). In: Structures, Structural Dynamics and Materials Conference, 18th, March 21-23, 1977, and Aircraft Composites: The Emerging Methodology for Structural Assurance, San Diego, Calif., March 24, 25, 1977, Technical Papers. Volume A. (A77-25726 10-39) New York, American Institute of Aeronautics and Astronautics, Inc., 1977, p. 311-331. 53 refs. (AIAA 77-415)

The review covers hybrid composites, that consist of two or more different types of fibers (or fiber composites) in a frequently repeated pattern in a laminate. The fibers considered are boron, graphite, glass, and Kevlar; the resins considered include mostly structural epoxies, with some utilization of polyimides and thermoplastics. The review shows that considerable data have been generated for the tensile strength properties, as well as tensile and thermal fatigue, of interply hybrids, and for the impact resistance of interply and intraply hybrids. The rule of mixtures appears to be adequate for predicting longitudinal and transverse mechanical properties of unidirectional interply hybrids, and linear laminate theory appears to be adequate for predicting the elastic response of hybrids.

**B.J. DATA SUMMARY:** Diverse data are presented; variables include tensile strength, tensile modulus, compressive strength, compressive modulus, flexural strength, flexural modulus, interlaminar shear strength, Poisson ratio, ply thickness, and fracture stress.

**A77-32241 \* #** Residual stresses in boron/tungsten and boron/carbon fibers. D. R. Behrendt (NASA, Lewis Research Center, Cleveland, Ohio). *Metallurgical Society of AIME, Annual Meeting, 106th, Atlanta, Ga., Mar. 6-10, 1977, Paper, 8 p.* 8 refs.

Longitudinal residual stress distribution is determined for 102-micron diam B/W and B/C fibers. The 102-micron diam B/W fibers are deposited on a 12.7-micron diam tungsten wire resistively heated in a BC13-H2 reactor. The 102-micron diam B/C fibers are made by deposition of boron on a pyrolytic graphite-coated carbon fiber. The longitudinal residual stress distribution is calculated from measurements of the change in length of the fiber produced by removal of the surface through electropolishing. It is found that for both types of fibers, the residual stress vary from a compressive stress

at the surface to a tensile stress in the boron near the core. Closer to the core and in the core, significant differences in the residual stresses are observed for the B/W and B/C fibers.

**S.D.**

**A77-35964 \*** Friction and wear behavior of graphite fiber reinforced polyimide composites. R. L. Fusaro and H. E. Sliney (NASA, Lewis Research Center, Cleveland, Ohio). *American Society of Lubrication Engineers, Annual Meeting, 32nd, Montreal, Canada, May 9-12, 1977, Preprint 77-AM-6C-1.1* p. 24 refs.

The friction and wear rate characteristics of 50/50 (weight per cent) graphite fiber-polyimide composites were studied by sliding metallic hemispherically tipped riders against disks made from the composites. Two different polyimides and two different graphite fibers were evaluated. Also studied were such variables as the effect of adding 10 per cent weight additions of powdered (CF-1.1)n, CdI2, or CdO, the effect of moisture in an air atmosphere, the effect of temperature, and the effect of different sliding speeds. In general,

wear to the metallic riders was negligible and composite wear increased at a constant rate as a function of number of sliding cycles.

**(Author)**

**A77-46521 \* #** Static behavior and the effects of thermal cycling in hybrid laminates. T. M. Liber, I. M. Daniel (IIT Research Institute, Chicago, Ill.), and C. C. Chamis (NASA, Lewis Research Center, Structures Section, Cleveland, Ohio). In: Discover reinforced plastics; Proceedings of the Thirty-second Annual Conference, Washington, D.C., February 8-11, 1977. (A77-46505 22-24) New York, Society of the Plastics Industry, Inc., 1977, p. 15-D-1 to

15-D-11.8 refs.

Static stiffness, strength and ultimate strain after thermal cycling were investigated for graphite/Kevlar 49/epoxy and graphite/S-glass/epoxy angle-ply laminates. Tensile stress-strain curves to failure and uniaxial tensile properties were determined, and theoretical predictions of modulus, Poisson's ratio and ultimate strain, based on linear lamination theory, constituent ply properties and measured strength, were made. No significant influence on tensile stress properties due to stacking sequence variations was observed. In general, specimens containing two 0-degree Kevlar or S-glass plies were found to behave linearly to failure, while specimens containing 4 0-degree Kevlar or S-glass plies showed some nonlinear behavior.

**J.M.B.**

**A77-46836 \* #** 10-deg off-axis test for shear properties in fiber composites. C. C. Chamis and J. H. Sinclair (NASA, Lewis Research Center, Composites Branch, Cleveland, Ohio). *Society for Experimental Stress Analysis, Spring Meeting, Dallas, Tex., May 15-20, 1977, Paper, 27 p.* 8 refs.

A combined theoretical and experimental investigation was conducted to assess the suitability of the 10-deg off-axis tensile test specimen for the intralaminar shear characterization of unidirectional composites. Composite mechanics, a combined-stress failure criterion, and a finite-element analysis were used to determine theoretically the stress-strain variation across the specimen width and the relative stress and strain magnitudes at the 10-deg plane. Strain gages were employed to measure the strain variation across the specimen width at specimen midlength and near the end tabs. Specimens from Mod-I/epoxy, T-300/epoxy, and S-glass/epoxy were used in the experimental program. It was found that the 10-deg off-axis tensile test specimen is suitable for intralaminar shear characterization, and it is recommended that it should be considered as a possible standard test specimen for such a characterization.

**(Author)**

**A77-47965 \* #** Thermal degradation of the tensile strength of unidirectional boron/aluminum composites. H. H. Grimes, R. A. Lad, and J. E. Maisel (NASA, Lewis Research Center, Cleveland, Ohio). *American Institute of Mining, Metallurgical and Petroleum Engineers, Spring Meeting, Atlanta, Ga., Mar. 6-11, 1977, Paper, 22 p.* 8 refs.

The variation of ultimate tensile strength with thermal treatment of B-Al composite materials and of boron fibers chemically removed from these composites is studied systematically in an attempt to determine the mechanism of the resulting strength degradation. The results indicate that thermally cycling of B-Al represents a more severe condition than equivalent time at temperature. Degradation of composite tensile strength from about 1.3 GN/sq m to as low as 0.34 GN/sq m was observed after 3000 cycles to 420 C for 203-micron B-1100 Al composite. In general, the 1100 Al-matrix composites degraded somewhat more than the 6061 matrix material studied. Measurement of fiber strengths confirmed a composite strength loss due to the degradation of fiber strength. Microscopy indicated a highly flawed fiber surface. On the basis of various thermal-cycling studies and electron diffraction analysis, a mechanism is favored in which B reacts with Al, freshly exposed by cold working during cycling, to form AlB2. The nonuniform interface reaction leads to a highly flawed and weakened B fiber.

**(Author)**

**N77-11114 \* #** IIT Research Inst., Chicago, Ill. **LAMINATION RESIDUAL STRESSES IN HYBRID COMPOSITES, PART 1 Final Report, 1 Jul. 1974 - 29 Feb. 1972**

I. M. Daniel and T. Liber Jun. 1976 168 p refs

(Contract NAS3-16766)

(NASA-CR-135085; IITRI-D6073-2-Pt-1)

Avail: NTIS

HC A08/MF A01 CSCL 11D

An experimental investigation was conducted to study lamination residual stresses for various material and loading parameters. The effects of hybridization on residual stresses and residual properties after thermal cycling under load were determined in

angle-ply graphite/Kevlar/epoxy and graphite/S-glass/epoxy laminates. Residual strains in the graphite plies are not appreciably affected by the type and number of hybridizing plies. Computed residual stresses at room temperature in the S-glass plies reach values up to seventy-five percent of the transverse strength of the material. Computed residual stresses in the graphite plies exceed the static strength by approximately ten percent. In the case of Kevlar plies, computed residual stresses far exceed the static strength indicating possible early failure of these plies. Static testing of the hybrids above indicates that failure is governed by the ultimate strain of the graphite plies. In thermally cycled hybrids, in general, residual moduli were somewhat lower and residual strengths were higher than initial values. Author

**N77-11115\*** IIT Research Inst., Chicago, Ill.  
**WAVE PROPAGATION IN FIBER COMPOSITE LAMINATES.**  
**PART 2 Final Report, 1 Jul. 1974 - 29 Feb. 1976**  
 I. M. Daniel and T. Libor Jun. 1976 135 p refs  
 (Contract NAS3-16766)  
 (NASA-CR-135086; ITRI-D6073-3-Pt-2) Avail: NTIS  
 HC A07/MF A01 CSCL 11D

An experimental investigation was conducted to determine the wave propagation characteristics, transient strains and residual properties in unidirectional and angle-ply boron/epoxy and graphite/epoxy laminates impacted with silicone rubber projectiles at velocities up to 250 MS-1. The predominant wave is flexural, propagating at different velocities in different directions. In general, measured wave velocities were higher than theoretically predicted values. The amplitude of the in-plane wave is less than ten percent of that of the flexural wave. Peak strains and strain rates in the transverse to the (outer) fiber direction are much higher than those in the direction of the fibers. The dynamics of impact were also studied with high speed photography. Author

**N77-11116\*** IIT Research Inst., Chicago, Ill.  
**STRAIN RATE EFFECTS ON MECHANICAL PROPERTIES OF FIBER COMPOSITES, PART 3 Final Report, 1 Jul. 1974 - 29 Feb. 1976**  
 I. M. Daniel and T. Libor Jun. 1976 49 p refs  
 (Contract NAS3-16766)  
 (NASA-CR-135087; ITRI-D6073-4) Avail: NTIS  
 HC A03/MF A01 CSCL 11D

An experimental investigation was conducted to determine the strain rate effects in fiber composites. Unidirectional composite specimens of boron/epoxy, graphite/epoxy, S-glass/epoxy and Kevlar/epoxy were tested to determine longitudinal, transverse and intralaminar (in-plane) shear properties. In the longitudinal direction the Kevlar/epoxy shows a definite increase in both modulus and strength with strain rate. In the transverse direction, a general trend toward higher strength with strain rate is noticed. The intralaminar shear moduli and strengths of boron/epoxy and graphite/epoxy show a definite rise with strain rate. Author

**N77-13153\*** CTL-Dixie, Inc., Cincinnati, Ohio.  
**DESIGN CONCEPTS FOR A COMPOSITE DOOR FRAME SYSTEM FOR GENERAL AUTOMOTIVE APPLICATIONS**  
 John A. Tauber Apr. 1976 56 p refs  
 (NASA Order C-79821-C)  
 (NASA-CR-135111) Avail: NTIS MF A01/HC A04 CSCL 11D

Conceptual design, manufacturing process, and costs are explored to determine the feasibility of replacing present steel parts in automotive door structures with various composite materials. The problems of conforming to present anti-intrusion specifications with advanced materials are examined and discussed. Modest weight reductions, at competitive costs, were identified for the utilization of specific composite materials in automotive door structures. Author

**N77-16101\*** TRW Inc., Cleveland, Ohio.  
**PMR POLYIMIDE/GRAPHITE FIBER COMPOSITE FAN BLADES**  
 P. J. Cavano and W. E. Winters 15 Dec. 1976 98 p refs  
 (Contract NAS3 18939)  
 (NASA-CR-135113; ER-7821F) Avail: NTIS  
 HC A05/MF A01 CSCL 11D

Ultrahigh speed fan blades, designed in accordance with the requirements of an ultrahigh tip speed blade axial flow compressor, were fabricated from a high strength graphite fiber tow and a PMR polyimide resin. The PMR matrix was prepared by combining three monomeric reactants in methyl alcohol, and the solution was applied directly to the reinforcing fiber for subsequent in situ polymerization. Some of the molded blades were completely finished by secondary bonding of root pressure pads and an electroformed nickel leading edge sheath prior to final machining. The results of the spin testing of nine PMR fan blades are given. Prior to blade fabrication, heat resin tensile properties of the PMR resin were examined at four formulated molecular weight levels. Additionally, three formulated molecular weight levels were investigated in composite form with both a high modulus and a high strength fiber, both as-molded and postcured, in room temperature and 232 C transverse tensile, flexure and short beam shear. Mixed fiber orientation panels simulating potential blade constructions were also evaluated. Flexure tests, short beam shear tests, and tensile tests were conducted on these angle-ply laminates. Author

**DATA SUMMARY.** Diverse data are presented; variables include tensile strength, modulus, weight loss, flexure strength, shear strength, dimensions, temperature

**N77-16114\*** Massachusetts Inst. of Tech., Cambridge Dept. of Materials Science and Engineering  
**SURFACE CRACK GROWTH IN FIBER COMPOSITES**  
**Interim Report, 1 Feb. 1976 - 1 May 1976**  
 J. Im, J. F. Mandell, S. F. Wang, and F. J. McGarry Sep. 1976 134 p refs  
 (Grant NSG-3044)  
 (NASA-CR-135094) Avail: NTIS HC A07/MF A01 CSCL 11D

The results of an experimental study of damage extension and failure in glass and graphite/epoxy laminates containing partially through-thickness surface cracks are presented. The laminates studied are divided between those containing four plies 90/0/0/90, 15/-15/15/15, and 45/-45/-45/45, and those containing 12-16 plies of the general configurations 0/90, 0/-45, and 0/+ or -60. Most of the results are for surface cracks of various lengths and several depths. Stable damage extension in laminates containing surface cracks is predominantly delamination between plies, and tends to be much more extensive prior to failure than is the case with through-thickness cracks, resulting in approximately notch insensitive behavior in most cases. A greater tendency for notch-sensitive behavior is found for 0/90 graphite/epoxy laminates for which stable damage extension is more limited. The rate of damage extension with increasing applied stress depends upon the composite system and ply configuration as well as the crack length and depth. An approximate semiempirical method is presented for estimating the growth rate of large damage regions. Author

**N77-30178\*** Stanford Research Inst., Menlo Park, Calif.  
**EFFECTS OF ILLUMINATION ON THE CONDUCTIVITY PROPERTIES OF SPACECRAFT INSULATING MATERIALS**  
**Final Report**  
 R. C. Adamos and J. E. Nanovic Jul. 1977 84 p refs  
 (Contract NAS3-20080, SRI Proj. 4904)  
 (NASA-CR-135201) Avail: NTIS HC A05/MF A01 CSCL 11D

Experimental data on the dark and illuminated conductivities of Kapton V and polyvinylidene fluoride (PVF2) films are described as well as the changes in insulating properties produced in

Kapton H, Kapton V, PVF2, and FEP Teflon films as result of prolonged exposure to solar illumination. An overall summary of the results of tests is presented. A general introduction and a description of the experimental apparatus and procedures used are also given.

Author

were 400 F and 100 psi for up to two hours duration. After postcure at temperatures up to 600 F, the composites demonstrated high initial mechanical properties at temperatures up to 550 F. The results from isothermal aging studies in air for 1000 hours indicated potential for long-term (over 1000 hours) use at 500 F and shorter-term use at 550 F.

(Author)

**A77-25733 \*** # Impact behavior of graphite-epoxy simulated fan blades. T. S. Cook (Southwest Research Institute, San Antonio, Tex.) and J. L. Preston, Jr. (United Technologies Corp., Power Systems Div., South Windsor, Conn.). In: Structures, Structural Dynamics and Materials Conference, 18th, March 21-23, 1977, and Aircraft Composites: The Emerging Methodology for Structural Assurance, San Diego, Calif., March 24, 25, 1977, Technical Papers, Volume A. (A77-25726 10-39) New York, American Institute of Aeronautics and Astronautics, Inc., 1977, p. 49-57. 12 refs. Contract No. NAS3-15568. (AIAA 77-365)

The response of a graphite-epoxy material, Modmor II/PR-286, to foreign object impact was investigated by impacting spherical projectiles of three different materials - gelatin, ice, and steel - on simulated blade specimens. Visual and metallographic inspection revealed three damage mechanisms: penetration, leading edge bending failure, and stress wave delamination and cracking. The steel projectiles caused penetration damage regardless of the impact location and angle. For the ice and gelatin particles impacting the leading edge, failure was due to large local bending strains, resulting in significant material removal and delamination damage.

B.J.

**DATA SUMMARY:** Attention is given to the effect of projectile characteristics, impact location and angle in the graphite-epoxy targets along with the effect of ply configuration; variables are projectile diameter, impact velocity, impact angle, impact location material removal, damage extent, and damage ratio; two figures and two tables include numeric data.

**A77-28347 \*** Superalloy eutectic composites with the VI A refractory elements - Cr, Mo and W. M. R. Jackson and J. L. Walter (General Electric Co., Schenectady, N.Y.). In: Superalloys: Metallurgy and manufacture; Proceedings of the Third International Symposium, Seven Springs, Pa., September 12-15, 1976. (A77-28321 11-26) Baton Rouge, La., Claitor's Publishing Division, 1976, p. 341-350. 42 refs. Contract No. NAS3-19711.

The paper discusses the phase equilibria for the ternary systems NiAlCr, NiAlMo, and NiAlW, with emphasis on reactions from the liquid state, although some of the solid state reactions are mentioned. It is shown that eutectics in the Ni-Al-refractory element (Cr, Mo, W) systems offer the potential for high-temperature turbine blade and vane applications. In particular, it is shown that the phase diagrams of these ternary systems can be manipulated to alter the eutectic phases and morphologies by simple quaternary alloying modifications. The resultant combination of chemistry and structure can be controlled to ensure a behavior that is well-matched to hot section component materials requirements.

S.D.

**A77-30919 \*** Poly /Diels-Alder/ matrix resins. R. J. Jones, M. K. O'Rell, C. H. Sheppard, and R. W. Vaughan (TRW Defense and Space Systems Group, Redondo Beach, Calif.). *SAMPE Quarterly*, vol. 8, Apr. 1977, p. 18-25. 15 refs. Contracts No. NAS3-15834; No. NAS3-17770.

A poly (Diels-Alder) (PDA) resin approach was investigated as a means to achieve autoclavability of high-temperature resistant resin/fiber composites under mild fabrication conditions. The results of the study were highly promising and program objectives were achieved. Low-void content Type A-S graphite reinforced composites were autoclave fabricated from a PDA resin/fiber prepreg prepared from an acetone:methanol:dioxane varnish. Autoclave conditions

## 26 INORGANIC AND PHYSICAL CHEMISTRY

Includes chemical analysis, e.g., chromatography; combustion theory; electrochemistry; and photochemistry.

For related information see also 77 *Thermodynamics and Statistical Physics*.

**N77-10165\*** National Aeronautics and Space Administration, Lewis Research Center, Cleveland, Ohio.

### REACTIONS OF CHROMIUM WITH GASEOUS NaCl IN AN OXYGEN ENVIRONMENT

Carl A. Stearns, Fred J. Kohl, and George C. Fryburg 1976 12 p refs Presented at Symp. on Properties of High Temp. Alloys, Las Vegas, Nev., 17-22 Oct. 1976; sponsored by the Electrochem. Soc. and the Met. Soc. of the Am. Inst. of Mining, Met. and Petrol. Engrs. (NASA-TM-X-73476; E-8748) Avail: NTIS HC A02/MF A01 CSCL 07D

Target collection techniques and high pressure mass spectrometric sampling have been used to study the formation of volatile chromium-containing species in the reaction of Cr<sub>2</sub>O<sub>3</sub> with O<sub>2</sub> and NaCl gases. Experiments were performed at atmospheric pressure as a function of chromium temperature, oxygen pressure, and NaCl gas concentration. The major chromium-containing vapor species were found to be (NaCl)<sub>x</sub> CrO<sub>3</sub> gas, with x = 1, 2, and 3, which are products of heterogeneous reactions on the surface. The kinetics indicate first order dependence on oxygen and sodium chloride pressures. Author

**N77-18238\*** National Aeronautics and Space Administration, Lewis Research Center, Cleveland, Ohio.

### DEVICE FOR THE DETECTION OF PHENOL AND RELATED COMPOUNDS Patent Application

Julian G. Schiller (Pittsburgh Univ.) and C. C. Liu, inventors (to NASA) (Pittsburgh Univ.) Filed 25 Feb. 1977 22 p (Grant NSG-3002)

(NASA-Case-LEW-12513-1; US-Patent-Appl-SN-772167) Avail: NTIS HC A02/MF A01 CSCL 07D

A method is described which permits the selective oxidation and potentiometric detection of phenol and related compounds in an electrochemical cell. An anode coated with a gel immobilized oxidative enzyme and a cathode are each placed in an electrolyte solution. The potential of the cell is measured by a potentiometer connected to the electrodes. NASA

**N77-18163\*** National Aeronautics and Space Administration, Lewis Research Center, Cleveland, Ohio.

### THE FLUORINATION OF COBALT AND ZINC

Patricia Marie O'Donnell Jul. 1976 112 p refs (NASA-TM-X-73478; E-8233) Avail: NTIS HC A06/MF A01 CSCL 07D

The reaction of cobalt and zinc with gaseous fluorine was studied. Both temperature and pressure were variables, ranging from 298 to 773 K and 50 to 625 torr. Both reactions were described by the parabolic rate law. The reaction was both temperature and pressure dependent. In the zinc reaction the vaporization rate of zinc above 573 K complicated the kinetics. The cobalt reaction was complex due to the formation of two fluorides. Parabolic rate constants have been calculated and from the temperature dependence of the reaction a heat of reaction of 2.8 kcal/mole sec for zinc and 4.8 kcal/mole sec for cobalt in the low temperature range has been estimated. A theoretical analysis indicated the most probable mechanism for both reactions is cation diffusion through cation vacancies. Comparisons with reported oxidation kinetics are given. Author

**N77-23222\*** National Aeronautics and Space Administration, Lewis Research Center, Cleveland, Ohio.

### DEVELOPMENT OF A DRIFT-CORRECTION PROCEDURE FOR A DIRECT-READING SPECTROMETER

Gilbert B. Chapman, II and William A. Gordon Washington May 1977 23 p refs (NASA-TN-D-8463; E-9004) Avail: NTIS HC A02/MF A01 CSCL 14B

A procedure which provides automatic correction for drifts in the radiometric sensitivity of each detector channel in a direct-reading emission spectrometer is described. Such drifts are customarily controlled by the regular analyses of standards, which provide corrections for changes in the excitational, optical, and electronic components of the instrument. This standardization procedure, however, corrects for the optical and electronic drifts. It is a step that must be taken if the time, effort, and cost of processing standards is to be minimized. This method of radiometric drift correction uses a 1,000-W tungsten-halogen reference lamp to illuminate each detector through the same optical path as that traversed during sample analysis. The responses of the detector channels to this reference light are regularly compared with channel response to the same light intensity at the time of analytical calibration in order to determine and correct for drift. Except for placing the lamp in position, the procedure is fully automated and compensates for changes in spectral intensity due to variations in lamp current. A discussion of the implementation of this drift-correction system is included. Author

**N77-33297\*** National Aeronautics and Space Administration, Lewis Research Center, Cleveland, Ohio.

### LEAN PREMIXED/PREVAPOORIZED COMBUSTION

A. H. Lafeyvre, ed. (Purdue Univ., Lafayette, Ind.) 21 Jan. 1977 46 p Presented at Workshop, Cleveland, Ohio, 20-21 Jan 1977

(NASA-CP-2016; E-9255) Avail: NTIS HC A03/MF A01 CSCL 21B

Recommendations were formulated on the status and application of lean premixed/prevaporized combustion to the aircraft gas turbine for the reduction of pollutant emissions. The approach taken by the NASA Stratospheric Cruise Emission Reduction Program (SCERP) in pursuing the lean premixed/prevaporized combustion technique was also discussed. The proceedings contain an overview of the SCERP program, the discussions and recommendations of the participants, and an overall summary. Author

**A77-19880 \*** Experimental investigation of flow turbulence effects on premixed methane-air flames. K. O. Smith (NASA, Lewis Research Center, Cleveland, Ohio; Cornell University, Ithaca, N.Y.) and F. C. Goudin (Cornell University, Ithaca, N.Y.), *American Institute of Aeronautics and Astronautics, Aerospace Sciences Meeting, 15th, Los Angeles, Calif., Jan. 24-26, 1977, Paper 77-183*, 8 p, 13 refs. Grant No. NSG 3019.

An experimental assessment of a novel technique for measuring turbulent flame speeds was conducted. Unconfined, V-shaped, methane-air flames stabilized in grid turbulence were investigated. Local flame speeds were measured employing hot film and laser anemometry, and fine wire thermocouples. The measurement instrumentation was extended to provide mean and fluctuating temperature information about turbulent flames. The flames in grid turbulence exhibited an increase in flame speed with increased length scale and velocity fluctuations. At high combustor velocities, stabilizer wake turbulence dominated the flame properties. (Author)

**A77-25148 \*** Surface studies of barium and barium oxide on tungsten and its application to understanding the mechanism of operation of an impregnated tungsten cathode. R. Forman (NASA, Lewis Research Center, Cleveland, Ohio), *Journal of Applied Physics* vol. 47, Dec. 1976, p. 5272-5279, 23 refs.

Surface studies have been made of multilayer and monolayer films of barium and barium oxide on a tungsten substrate. The



purpose of the investigation was to synthesize the surface conditions that exist on an activated impregnated tungsten cathode and obtain a better understanding of the mechanism of operation of such cathodes. The techniques employed in these measurements were Auger spectroscopy and work-function measurements. The results of this study show that the surface of an impregnated cathode is identical to that observed for a synthesized monolayer or partial monolayer of barium on oxidized tungsten by evaluating Auger spectra and work-function measurements. Data obtained from desorption studies of barium monolayers on a tungsten substrate in conjunction with Auger and work-function results have been interpreted to show that throughout most of its life an impregnated cathode has a partial monolayer, rather than a monolayer, of barium on its surface. (Author)

**A77-38370 \*** Investigation of the formation of gaseous sodium sulfate in a doped methane-oxygen flame. C. A. Stearns, R. A. Miller, F. J. Kohl, and G. C. Fryburg (NASA, Lewis Research Center, Cleveland, Ohio). *Electrochemical Society, Journal*, vol. 124, July 1977, p. 1145, 1146. 5 refs.

Na<sub>2</sub>SO<sub>4</sub>(g) formation was measured at atmospheric pressure in CH<sub>4</sub>-O<sub>2</sub> flames, with high pressure, free-jet expansion, mass spectrometric sampling used to identify and measure reaction products. Measured composition profiles of reaction products for a doped 9.5 mole ratio O<sub>2</sub>/CH<sub>4</sub> flame are presented. Weight percentages of reactants were 4.7 CH<sub>4</sub>, 89.0 O<sub>2</sub>, 3.5 H<sub>2</sub>O, 2.0 SO<sub>2</sub> and 0.35 NaCl. B.J.

**A77-47862 \*** Ion chromatographic determination of anions collected on filters at altitudes between 9.6 and 13.7 kilometers. D. A. Otterson (NASA, Lewis Research Center, Cleveland, Ohio). *U.S. Environmental Protection Agency, Symposium on Ion Chromatographic Analysis on Environmental Pollutants, Research Triangle Park, N.C., Apr. 28, 1977, Paper*. 15 p.

**A77-48694 \*** Theoretical and experimental studies of the deposition of Na<sub>2</sub>SO<sub>4</sub> from seeded combustion gases. F. J. Kohl, G. J. Santoro (NASA, Lewis Research Center, Cleveland, Ohio), and G. C. Fryburg (Yale University, New Haven, Conn.). *Electrochemical Society, Symposium on Corrosion Problems Involving Volatile Corrosion Products, Philadelphia, Pa., May 12, 1977, Paper*. 28 p. 17 refs.

A basic point in the hot corrosion of turbine components is the deposition of sodium sulfate from flames containing sodium and sulfur. An experimental study is described which examines a dew point prediction theory based on the local thermochemical equilibrium (LTCE) method, and a means to calculate the deposition rate is suggested. In addition, a convective diffusion theory, based on the assumption of a chemically frozen boundary layer, utilizing the LTCE results, and imposing the additional effects of mass transport, was also successful in predicting dew points for Na<sub>2</sub>SO<sub>4</sub>-seeded combustion gases. A multicomponent mass transfer equation was derived to predict Na<sub>2</sub>SO<sub>4</sub> deposition rate via vapor transport at temperatures below the deposition onset temperature. S.C.S.

**A77-48695 \*** Gaseous sodium sulfate formation in flames and flowing gas environments. C. A. Stearns, R. A. Miller, F. J. Kohl, and G. C. Fryburg (NASA, Lewis Research Center, Cleveland, Ohio). *Electrochemical Society, Symposium on Corrosion Problems Involving Volatile Corrosion Products, Philadelphia, Pa., May 12, 1977, Paper*. 21 p. 26 refs.

Formation of Na<sub>2</sub>SO<sub>4</sub>(g) in flames and hot flowing gas systems was studied by high pressure, free-jet expansion, modulated molecular beam mass spectrometric sampling. Fuel-lean CH<sub>4</sub>-O<sub>2</sub> flames doped with SO<sub>2</sub>, H<sub>2</sub>O and NaCl yielded the gaseous Na<sub>2</sub>SO<sub>4</sub> molecule in residence times of less than one millisecond. Inter-

mediate species NaSO<sub>2</sub>(g) and NaSO<sub>3</sub>(g) were also observed and measured. Composition profiles were obtained for all reaction products. Non-flame flowing gas experiments showed that Na<sub>2</sub>SO<sub>4</sub> and NaSO<sub>3</sub> gaseous molecules were formed at 1140 C in mixtures of O<sub>2</sub>, H<sub>2</sub>O(g), SO<sub>2</sub> and NaCl(g). Experimental results are compared with calculated equilibrium thermodynamic predictions. (Author)

**N77-28249\*#** Pennsylvania State Univ., University Park. Dept. of Mechanical Engineering. **COMBUSTION OF LIQUID SPRAYS AT HIGH PRESSURES Annual Report, 1976**

A. J. Shearer and G. M. Faeth Mar. 1977 90 p refs (Grant NGR-39-009-077)

(NASA-CR-135210) Avail: NTIS HC A05/MF A01 CSCL 21B

The combustion of pressure atomized fuel sprays in high pressure stagnant air was studied. Measurements were made of flame and spray boundaries at pressures in the range 0.1-9 MPa for methanol and n-pentane. At the higher test pressure levels, critical phenomena are important. The experiments are compared with theoretical predictions based on a locally homogeneous two-phase flow model. The theory correctly predicted the trends of the data, but underestimates flame and spray boundaries by 30-50 percent, indicating that slip is still important for the present experiments (Sauter mean diameters of 30 microns at atmospheric pressure under cold flow conditions). Since the sprays are shorter at high pressures, slip effects are still important even though the density ratio of the phases approach one another as the droplets heat up. The model indicates the presence of a region where condensed water is present within the spray and provides a convenient means of treating supercritical phenomena. Author

**N77-28250#** National Bureau of Standards, Washington, D. C. **HAZARD CHARACTERISTICS OF COMBUSTION PRODUCTS IN FIRES: THE STATE-OF-THE-ART REVIEW Final Report**

Merritt M. Birky May 1977 48 p refs

(NASA Order C-97823-B)

(NASA-CR-135088; NBSIR-77-1234)

Avail: NTIS

HC A03/MF A01 CSCL 21B

The smoke inhalation hazard as related to human fatalities is reviewed, and the limitations of the fire fatality data and the methods that have been and are being used to assess the inhalation toxicity hazard are outlined. In depth autopsy studies of some of these fatalities show that carbon monoxide is the predominant toxicant produced from fires. Chemical analysis of combustion products has been used extensively to assess the toxicological hazard in fire research. The limitations of such measurements are addressed and a combination of toxicology (animal exposures) and analytical chemistry is recommended. The mechanism of toxic action of a few well known combustion products is discussed. Due to the extensive use of organophosphates as fire retardants in polymeric materials, the toxicity of this class of compounds is reviewed in some detail. Author

**A77-21698 \*** Simulation of fluidized bed combustors. I. Combustion efficiency and temperature profile. M. Horio and C. Y. Wen (West Virginia University, Morgantown, W. Va.). *American Institute of Chemical Engineers, Annual Meeting, 69th, Chicago, Ill., Nov. 28-Dec. 2, 1976, Paper*. 58 p. 30 refs. Contract No. NAS3-19725.

A chemical engineering analysis is made of fluidized-bed combustor (FBC) performance, with FBC models developed to aid estimation of combustion efficiency and axial temperature profiles. The FBC is intended for combustion of pulverized coal and a pressurized FBC version is intended for firing gas turbines by burning coal. Transport phenomena are analyzed at length: circulation, mixing models, drifting, bubble wake lift, heat transfer, division of the FB reactor into idealized mixing cells. Some disadvantages of a

coal FBC are pointed out: erosion of immersed heat-transfer tubing, complex feed systems, carryover of unburned coal particles, high particulate omission in off-streams. The low-temperature bed (800-950 C) contains limestone, and flue-gas-entrained SO<sub>2</sub> and NO<sub>x</sub> can be kept within acceptable limits.

R.D.V.

**A77-33355 \* #** Process sensitivity studies of the Westinghouse Sulfur Cycle for hydrogen generation. R. Carty, J. Funk, M. Soliman, W. Conger (Kentucky, University, Lexington, Ky.), L. Brecher, S. Spewock (Westinghouse Research Laboratories, Pittsburgh, Pa.), and K. Cox. In: World Hydrogen Energy Conference, 1st, Miami Beach, Fla., March 1-3, 1976, Proceedings. Volume 1. (A77-33326 14-44) Coral Gables, Fla., University of Miami; New York, Pergamon Press, 1976, p. 9A-17 to 9A-28. Contract No. NAS3-18934.

The effect of variations of acid concentration, pressure, and temperature on the thermal process efficiency of the Westinghouse Sulfur Cycle was examined using the University of Kentucky's HYDRGN program. Modifications to the original program were made to duplicate the process flow sheet and take into account combined-cycle heat-to-work efficiencies for electrochemical work requirements, aqueous solutions, and heat-of-mixing effects. A total of 125 process variations were considered (acid concentration: 50-90 w/o; pressure: 15-750 psia; temperature: 922-1366 K (2000 F)). The methods of analysis, results, and conclusions are presented. (Author)

**A77-33356 \* #** Hydrogen production by water decomposition using a combined electrolytic-thermochemical cycle. G. H. Farberman and L. E. Brecher (Westinghouse Electric Corp., Pittsburgh, Pa.). In: World Hydrogen Energy Conference, 1st, Miami Beach, Fla., March 1-3, 1976, Proceedings. Volume 1. (A77-33326 14-44) Coral Gables, Fla., University of Miami; New York, Pergamon Press, 1976, p. 9A-29 to 9A-50. Contract No. NAS3-18934.

A proposed dual-purpose power plant generating nuclear power to provide energy for driving a water decomposition system is described. The entire system, dubbed Sulfur Cycle Water Decomposition System, works on sulfur compounds (sulfuric acid feed-stock, sulfur oxides) in a hybrid electrolytic-thermochemical cycle; performance superior to either all-electrolysis systems or presently known all-thermochemical systems is claimed. The 3345 MW(th) graphite-moderated helium-cooled reactor (VHTR - Very High Temperature Reactor) generates both high-temperature heat and electric power for the process; the gas stream at core exit is heated to 1850 F. Reactor operation is described and reactor awards are illustrated. A cost assessment for on-stream performance in the 1990's is optimistic.

R.D.V.

**N77-19206\*** National Bureau of Standards, Washington, D.C. Inst. for Basic Standards.

**OVERVIEWS AND JUSTIFICATIONS FOR LOW GRAVITY EXPERIMENTS ON PHASE TRANSITION AND CRITICAL PHENOMENA IN FLUIDS** Interim Report

M. R. Moldover, R. J. Hocken, R. W. Gammon (Md. Univ. College Park), and J. V. Sengers (Md. Univ. College Park) Oct. 1976 105 p refs

(NASA Order C-62861-C)

(NASA-CR-149884; PB-258944/B; NBS-TN-925) Avail: NTIS HC A06/MF A01 CSCL 07D

Questions about thermodynamic properties, transport properties, and the complex nonlinear phenomena which occur when fluids undergo phase transitions in the critical region are considered. The limitations to answering these questions by experiments in the earth's gravitational field are discussed. The distinction is made between practical limits which may be extended by advances in technology and intrinsic ones which arise from the modification of fluid properties by the earth's gravitational field. The kinds of experiments near critical points which could best exploit the low gravity environment of an orbiting laboratory are identified. These include studies of the index of refraction, constant volume, specific heat, and phase separation. GRA

**A77-48158 \*** Symposium on Combustion /International/, 16th, Massachusetts Institute of Technology, Cambridge, Mass., August 15-20, 1976, Proceedings. Symposium sponsored by the Combustion Institute, U.S. Air Force, U.S. Navy, U.S. Army, ERDA, NASA, NSF, American Chemical Society, et al.; NSF Grant No. ENG-76-21419; Contracts No. N00014-76-G-0041; No. NAS3-19774; Grant No. DAAD05-76-Q-5603, Pittsburgh, Pa., Combustion Institute, 1977, 1724 p. Members, \$37.; nonmembers, \$60. (For individual items see A77-48159 to A77-48250)

Aspects of combustion technology in power systems are considered, taking into account a combustion in large boilers, the control of over-all thermal efficiency of combustion heating systems, a comparison of mathematical models of the radiative behavior of a large-scale experimental furnace, a concentric multiannular swirl burner, and the effects of water introduction on diesel engine combustion and emissions. Attention is also given to combustion and related processes in energy production from coal, spray and droplet combustion, soot formation and growth, the kinetics of elementary reactions, flame structure and chemistry, propellant ignition and combustion, fire and explosion research, mathematical modeling, high output combustion systems, turbulent flames and combustion, and ignition, optical, and electrical properties.

G.R.

## 26 METALLIC MATERIALS

Includes physical, chemical, and mechanical properties of metals, e.g., corrosion; and metallurgy.

**N77-10183\*** National Aeronautics and Space Administration, Lewis Research Center, Cleveland, Ohio.

### HOT CORROSION STUDIES OF FOUR NICKEL-BASE SUPERALLOYS: B-1900, NASA-TRW VIA, 713C AND IN738

George C. Fryburg, Fred J. Kohl, and Carl A. Stearns 1976 11 p refs Presented at Symp. on Properties of High Temp. Alloys, Las Vegas, Nev., 17-22 Oct. 1976; sponsored by the Electrochem. Soc. and the Met. Soc. of the Am. Inst. of Mining, Met. and Petrol. Engrs.

(NASA-TM-X-73479) Avail: NTIS HC A02/MF A01 CSCL 11F

The susceptibility to hot corrosion of four nickel base superalloys has been studied at 900 deg and 1000 deg C in one atmosphere of slowly flowing oxygen. Hot corrosion was induced by coating the samples with known doses of Na<sub>2</sub>SO<sub>4</sub> and oxidizing the coated samples isothermally on a sensitive microbalance. In general, the order of susceptibility found was: B-1900 is greater than 713C is greater than NASA-TRW VIA and is greater than IN738. This order corresponds to the order of decreasing molybdenum content of the alloys. Chemical evidence for B-1900 indicates that hot corrosion is instigated by acid fluxing of the protective Al<sub>2</sub>O<sub>3</sub> coating by MoO<sub>3</sub>.

Author

**N77-11155\*** National Aeronautics and Space Administration, Lewis Research Center, Cleveland, Ohio.

### HOT HARDNESS OF NICKEL-RICH NICKEL-CHROMIUM-ALUMINUM ALLOYS

Stanley R. Levine Washington Oct. 1976 18 p refs Prepared in cooperation with Army Air Mobility Res. and Develop. Lab., Cleveland, Ohio

(NASA-TM-X-3429; E-8750) Avail: NTIS HC A02/MF A01 CSCL 11F

Rockwell A hardness of cast nickel-chromium-aluminum (NiCrAl) alloys was examined from ambient to 1150 K and compared to cast NiAl and IN-100. Alloy constitution was either gamma, gamma prime + gamma or gamma + beta + alpha + gamma prime. Below 1000 K beta containing NiCrAl alloys have hardnesses comparable to IN-100; above 1000 K they soften faster than IN-100. At 1150 K the hardness of beta-containing NiCrAl alloys decreases with increasing beta-content. The beta-containing NiCrAl alloys were harder than beta-NiAl. The ultimate tensile strengths of the NiCrAl alloys were estimated. The effects of NiCrAl coatings on strength and fatigue life of cooled turbine components were deduced.

Author

**N77-12184\*** National Aeronautics and Space Administration, Lewis Research Center, Cleveland, Ohio.

### EFFECT OF A CHROMIUM-CONTAINING FUEL ADDITIVE ON HOT CORROSION

Carl E. Lowell and Daniel L. Deadmore Jul. 1976 30 p refs (NASA-TM-X-73465; E-8831) Avail: NTIS HC A03/MF A01 CSCL 11F

Four superalloys were tested at 900 C in high velocity combustion gases containing synthetic sea salt and, in some cases, a chromium containing fuel additive. While the additive reduced hot corrosion of the alloys over the 100 hour test period, the attack was not eliminated nor was the mode of attack changed. Reduction of the number of thermal cycles had as large a beneficial effect as the Cr additive. Intermittent washing during testing had either small beneficial or adverse effects depending on the alloy.

Author

**N77-12185\*** National Aeronautics and Space Administration, Lewis Research Center, Cleveland, Ohio.

### DIRECTIONALLY SOLIDIFIED IRON-BASE EUTECTIC ALLOYS

Surendra N. Tewari Washington Dec 1976 25 p refs (NASA-TN-D-8354; E-8846) Avail: NTIS HC A02/MF A01 CSCL 11F

Pseudobinary eutectic alloys with nominal compositions of Fe-25Ta-22Ni-10Cr and Fe-15.5Nb-14.5Ni-6.0Cr were directionally solidified at 0.5 centimeter per hour. Their microstructure consisted of the fcc, iron solid-solution, matrix phase reinforced by about 41-volume-percent, hcp, faceted Fe<sub>2</sub>Ta fibers and 41-volume-percent, hcp, Fe<sub>2</sub>Nb lamellae for the tantalum- and niobium-containing alloys, respectively. The microstructural stability under thermal cycling and the temperature dependence of tensile properties were investigated. These alloys showed low elevated-temperature strength and were not considered suitable for application in aircraft-gas-turbine blades although they may have applicability as vane materials.

Author

**N77-13209\*** National Aeronautics and Space Administration, Lewis Research Center, Cleveland, Ohio.

### PHASE DIAGRAMS OF METALLIC SYSTEMS (ALPHABETIC CUMULATIVE ALLOY SYSTEM INDEX AND TABLE OF CONTENTS)

N. V. Ageev, ed. Washington Dec. 1976 107 p Transl into ENGLISH from the book "Diagrammy sostoyaniya metallicheskih sistem", v. 1-19, Moscow, VINITI Press, 1959 - 1976. Selected pages

(NASA-TT-F-17296) Avail: NTIS HC A06/MF A01 CSCL 11F

The compilation of phase diagram information is the most comprehensive publication available on phase diagram information for binary, ternary, and higher order alloy systems. The Tables of Contents in volumes 1 through 17 of compilation do not list the contents by alphabetic chemical symbols, but in Russian. Volumes 18 and 19 have their Tables of Contents listed by alphabetic chemical symbol. It is a laborious task to use this compilation because no cumulative alloy system index is available. This translation provides individual volume listing of contents by page number with alphabetic chemical symbols and it provides a cumulative alloy system index, listing alloys systems alphabetically by chemical symbol. This publication should facilitate the use of this valuable information source.

Author

**N77-14253\*** National Aeronautics and Space Administration, Lewis Research Center, Cleveland, Ohio.

### EFFECT OF CYCLIC CONDITIONS ON THE DYNAMIC OXIDATION OF GAS TURBINE SUPERALLOYS

James R. Johnston and Richard L. Ashbrook Apr. 1974 24 p refs

(NASA-TN-D-7614; E-7594) Avail: NTIS HC A02/MF A01 CSCL 11F

The effects of operating parameters of a dynamic apparatus used to study oxidation and thermal fatigue of gas turbine materials were studied. IN-100, TD-NiCr, and W1-52 were tested at a maximum temperature of 1,090 deg C. Heating time per cycle was varied from 1/20 hr to 10 hr. Minimum temperatures between heating cycles were room temperature, 430 deg, and 650 deg C. Cooling air velocities were zero, Mach 0.7, and Mach 1. Increasing the number of cycles for a given time at temperature increased weight loss. Thermal fatigue was related to number of cycles more than to time at temperature.

Author

**DATA SUMMARY:** 3 alloys were subjected to cyclic heating and cooling; variables are chemical composition, heating time per cycle, cooling air velocity, minimum cooling air temperature, weight change, thermal fatigue cracking; 9 figures and 3 tables include numeric data.

**N77-18147\*** National Aeronautics and Space Administration, Lewis Research Center, Cleveland, Ohio.

**DIRECTIONALLY SOLIDIFIED EUTECTIC ALLOY GAMMA-BETA**

Surendra N. Tawari (Natl. Res. Council) Washington Jan. 1977 27 p refs Presented in part at the 105th Annual Meeting of the Am. Inst. of Mining, Metallurgical, and Petroleum Engineers, Las Vegas, Nev., 22-26 Feb. 1976

(NASA-TN-D-8365; E-8845) Avail: NTIS HC A03/MF A01 CSCI 11F

A pseudobinary eutectic alloy composition was determined by a previously developed bleed-out technique. The directionally solidified eutectic alloy with a composition of Ni-37.4Fe-10.0Cr-9.6Al (in wt%) had tensile strengths decreasing from 1,090 MPa at room temperature to 54 MPa at 1,100 C. The low density, excellent microstructural stability, and oxidation resistance of the alloy during thermal cycling suggest that it might have applicability as a gas turbine vane alloy while its relatively low high temperature strength precludes its use as a blade alloy. A zirconium addition increased the 750 C strength, and a tungsten addition was ineffective. The gamma - beta eutectic alloys appeared to obey a normal freezing relation. Author

**DATA SUMMARY:** Mechanical properties, oxidation and heat resistance of solidified iron-nickel-chromium-aluminum alloy; variables include crystal growth rate, tensile strength, temperature effects, yield strength, elongation, reduction in area, intermetallics, chemical composition, microstructure; 6 figures and 3 tables are included.

**N77-18148\*** National Aeronautics and Space Administration, Lewis Research Center, Cleveland, Ohio.

**OXIDATION IN OXYGEN AT 900 DEG AND 1000 DEG C OF FOUR NICKEL-BASE CAST SUPERALLOYS: NASA-TRW VIA, B-1900, ALLOY 713C, AND IN-738**

George C. Fryburg, Fred J. Kohl, and Carl A. Stearns Washington Jan. 1977 45 p refs

(NASA-TN-D-8388; E-8770) Avail: NTIS HC A03/MF A01 CSCI 11F

The oxidation at 900 and 1,000 C of four nickel-base superalloys in 1 atmosphere of slowly flowing oxygen was investigated. Thermogravimetric rate data were obtained for periods to 100 hours. The morphology and composition of the oxide scales formed after 100 hours were studied by optical microscopy, X-ray diffraction, electron microprobe, scanning electron microscopy, and X-ray photoelectron spectroscopy (ESCA). Alloys B-1900 and VIA were found to be primarily alumina formers, though probably 25 percent of their surface was covered by Cr<sub>2</sub>O<sub>3</sub>-containing oxides at 900 C. Alloys 713C and IN-738 were primarily chromia formers, though the surface of 713C at 1,000 C was covered with NiO, and the surface of IN-738 at both temperatures was covered with a thin layer of TiO<sub>2</sub>. Author

**DATA SUMMARY:** Five different experimental techniques were applied to determine the morphology and composition of the complex oxide scales formed on nickel-base superalloys oxidized at high temperature; variables include temperature, time, weight change, diffraction pattern intensity, rate of oxidation, thickness of oxide layer, thickness of internal oxidation zone, thickness of gamma prime depletion zone, composition; 7 figures and 4 tables include numeric data.

**N77-17200\*** National Aeronautics and Space Administration, Lewis Research Center, Cleveland, Ohio.

**REACTION DIFFUSION IN THE NICKEL-CHROMIUM-ALUMINUM AND COBALT-CHROMIUM-ALUMINUM SYSTEMS**

Stanley R. Levine Washington Feb. 1977 67 p refs Prepared in cooperation with Army Air Mobility Lab., Moffett Field, Calif. (NASA-TN-D-8383; E-8835) Avail: NTIS HC A04/MF A01 CSCI 11F

The effects of MCrAl coating-substrate interdiffusion on oxidation life and the general multiphase, multicomponent diffusion problem were examined. Semi-infinite diffusion couples that had sources representing coatings and sinks representing gas turbine

alloys were annealed at 1,000, 1,095, 1,150, or 1,205 C for as long as 500 hours. The source and sink aluminum and chromium contents and the base metal (cobalt or nickel) determined the parabolic diffusion rate constants of the couples and predicted finite coating lives. The beta source strength concept provided a method (1) for correlating beta recession rate constants with composition, (2) for determining reliable average total, diffusion, and constitutional activation energies; and (3) for calculating interdiffusion coefficients. Author

**DATA SUMMARY:** Driving potentials, phase fields, and layer growth contents for 28 Al source alloys are presented, along with layer growth analysis of Ni and Co base alloys; variables include Al content weight percent, Cr content weight percent, distance, Knoop hardness number, time, recession, source strength, recession rate constant, growth, and total depleted zone growth; 13 figures and 5 tables include numeric data.

**N77-17201\*** National Aeronautics and Space Administration, Lewis Research Center, Cleveland, Ohio.

**HOT CORROSION OF S-57, 1 COBALT-BASE ALLOY**

Gilbert J. Santoro Washington Feb. 1977 34 p refs (NASA-TN-D-8395; E-8876) Avail: NTIS HC A03/MF A01 CSCI 11F

A cobalt base alloy, S-57, was hot corrosion tested in Mach 0.3 burner rig combustion gases at maximum alloy temperatures of 900 and 1000 C. Various salt concentrations were injected into the burner: 0.5, 2, 5, and 10 ppm synthetic sea salt and 4 ppm sodium sulfate (Na<sub>2</sub>SO<sub>4</sub>). S-57 underwent accelerated corrosion only under the most severe test conditions, for example, 4 ppm Na<sub>2</sub>SO<sub>4</sub> at 900 C. The process of the accelerated corrosion was primarily sulfidation. Author

**DATA SUMMARY:** High temperature sulfur-sea salt corrosion in Mach 0.3 burner rig combustion gases; variables are temperature, corrosive penetration depth, exposure time, sulfur content, sea salt concentration, burner rig flame fuel, oxidant mass ratio, oxide phase, alloy temperature, weight of deposit, and scale thickness; 8 figures and 6 tables include numeric data.

**N77-18249\*** National Aeronautics and Space Administration, Lewis Research Center, Cleveland, Ohio.

**WELDABILITY OF HIGH-TOUGHNESS IRON - 12 PERCENT-NICKEL ALLOYS WITH REACTIVE METAL ADDITIONS OF TITANIUM, ALUMINUM, OR NIOBIUM**

Jack H. Delvetian (Youngstown State Univ., Ohio), Joseph R. Stephens, and Walter R. Witzke Washington Feb. 1977 23 p refs

(NASA-TN-D-8403; E-8883) Avail: NTIS HC A02/MF A01 CSCI 11F

Three exceptionally high toughness Fe-12Ni alloys designed for cryogenic service were welded by using the gas tungsten arc welding process. Evaluation of their weldability included equivalent energy fracture toughness tests, transverse weld tensile tests at -196 and 25 C, and weld crack sensitivity tests. The Fe-12Ni-0.25Ti alloy proved extremely weldable for cryogenic applications, having weld and heat affected zone properties comparable to those of the wrought base alloy. The Fe-12Ni-0.5Al alloy had good weld properties only after the weld joint was heat treated. The Fe-12Ni-0.25Nb alloy was not considered weldable for cryogenic use because of its poor weld joint properties at -196 C and its susceptibility to hot cracking. Author

**DATA SUMMARY:** Effects of gas tungsten arc welding on Fe-12Ni alloy sheets containing titanium, aluminum, or niobium additions; the variables include fracture toughness, weld cooling rate, heat treatment, hot rolling, yield strength, tensile strength, elongation (percent), alloy content, interstitial content, and microstructure; 8 figures and 3 tables.

**N77-18251\*** National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio.

# **OPTICAL PROPERTIES OF ION BEAM TEXTURED METALS**

W. R. Hudson, A. J. Weigand, and M. J. Mirtich 1977 20 p refs Presented at the 6th Annual Symp. on Applied Vacuum Science and Technology, Tampa, Fla., 14-16 Feb. 1977; sponsored by the Am. Vacuum Soc.

(NASA-TM-X-73598; E-9073) Avail: NTIS HC A02/MF A01 CSCL 11F

Copper, silicon, aluminum, titanium and 316 stainless steel were textured by 1000 eV xenon ions from an 8 cm diameter electron bombardment ion source. Simultaneously sputter-deposited tantalum was used to facilitate the development of the surface microstructure. Scanning electron microscopy of the ion textured surfaces revealed two types of microstructure. Copper, silicon, and aluminum developed a cone structure with an average peak-to-peak distance ranging from 1 micron for silicon to 6 microns for aluminum. Titanium and 316 stainless steel developed a serpentine ridge structure. The average peak-to-peak distance for both of these materials was 0.5 micron. Spectral reflectance was measured using an integrating sphere and a holmium reflectometer. Total reflectance for air mass 0 and 2, solar absorptance and total emittance normalized for a 425 K black body were calculated from the reflectance measurements.

Author

**DATA SUMMARY:** Spectral reflectance for five specimens of ion beam textured metals; variables include wavelength, reflectance, percent of total energy, air mass zero, air mass two.

**N77-19208\*** National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio.

# **A DIRECTIONALLY SOLIDIFIED IRON-CHROMIUMALUMINUM-TANTALUM CARBIDE EUTECTIC ALLOY**

Fredric H. Harf Washington Mar. 1977 19 p refs (NASA-TM-X-3434; E-8890) Avail: NTIS HC A02/MF A01 CSCL 11F

A eutectic alloy, Fe-13.6Cr-3.7Al-9TaC, was directionally solidified in a high gradient furnace, producing a microstructure of aligned TaC fibers in an oxidation resistant alpha-iron matrix. Tensile and stress rupture properties, thermal cycling resistance, and microstructures were evaluated. The alloy displays at 1000 C an ultimate tensile strength of 58 MPa and a 100-hour rupture life at a stress of 21 MPa. Thermal cycling to 1100 C induces faceting in the TaC fibers.

Author

**DATA SUMMARY:** Tensile and stress rupture tests of directionally solidified, as cast, and oxide dispersion strengthened alloys; variables include nominal composition (wt %), temperature, ultimate tensile strength, yield strength, elongation, solidification rate, stress, life; 1 figure and 2 tables include numeric data.

**N77-19209\*** National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio.

# **GASEOUS SODIUM SULFATE FORMATION IN FLAMES AND FLOWING GAS ENVIRONMENTS**

Carl A. Stearns, Robert A. Miller, Fred J. Kohl, and George C. Frybuig 1977 22 p refs Presented at Symp. on Corrosion Probl. Involving Volatile Corrosion Products, Philadelphia, 8-13 May 1977; Sponsored by the Electrochem. Soc.

(NASA-TM-X-73600; E-9029) Avail: NTIS HC A02/MF A01 CSCL 11F

Formation of Na<sub>2</sub>SO<sub>4</sub>(g) in flames and hot flowing gas systems was studied by high pressure, free-jet expansion, modulated molecular beam mass spectrometric sampling. Fuel-lean CH<sub>4</sub>-O<sub>2</sub> flames doped with SO<sub>2</sub>, H<sub>2</sub>O and NaCl yielded the gaseous Na<sub>2</sub>SO<sub>4</sub> molecule in residence times of less than one millisecond. Intermediate species NaSO<sub>2</sub>(g) and NaSO<sub>3</sub>(g) were also observed and measured. Composition profiles were obtained for all reaction products. Nonflame flowing gas experiments showed that Na<sub>2</sub>SO<sub>4</sub> and NaSO<sub>3</sub> gaseous molecules were formed at 1140 C in mixtures of O<sub>2</sub>, H<sub>2</sub>O(g), SO<sub>2</sub> and NaCl(g). Experimental results are compared with calculated equilibrium thermodynamic predictions.

Author

**DATA SUMMARY:** Measurements of various gaseous species in flames; variables include ion intensity, burner surface to sampling orifice distance, composition, fuel/oxidant mass ratio, temperature, and equilibrium constant; 4 figures and 2 tables include numeric data.

**N77-19211\*** National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio.

# **CREEP DEGRADATION IN OXIDE-DISPERSION-STRENGTHENED ALLOYS**

J. Daniel Whittenberger Washington Mar. 1977 36 p refs (NASA-TN-D-8421; E-8849) Avail: NTIS HC A03/MF A01 CSCL 11F

Oxide dispersion strengthened Ni-base alloys in wrought bar form are studied for creep degradation effects similar to those found in thin gage sheet. The bar products evaluated included ODS-Ni, ODS-NiCr, and three types of advanced ODS-NiCrAl alloys. Tensile test specimens were exposed to creep at various stress levels at 1365 K and then tensile tested at room temperature. Low residual tensile properties, change in fracture mode, the appearance of dispersoid-free bands, grain boundary cavitation, and internal oxidation in the microstructure were interpreted as creep degradation effects. This work showed that many ODS alloys are subject to creep damage. Degradation of tensile properties occurred after very small amounts of creep strain, ductility being the most sensitive property. All the ODS alloys which were creep damaged possessed a large grain size. Creep damage appears to have been due to diffusional creep which produced dispersoid-free bands around boundaries acting as vacancy sources. Low angle and possibly twin boundaries acted as vacancy sources.

Author

**DATA SUMMARY:** Diffusional creep and creep damage in nickel based alloys possessing large grain size; the variables include chemical composition, heat treatment, thermal stress, mechanical processing, grain size parameters, crystal structure, residual tensile properties, reduction in area, elongation, stress-strain-time relations; 3 figures and 5 tables.

**N77-20201\*** National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio.

# **ZIRCONIUM MODIFIED NICKEL-COPPER ALLOY Patent**

John D. Whittenberger, inventor (to NASA) Issued 15 Mar. 1977 5 p Filed 5 Jun. 1975 Supersedes N75-26087 (13-17, p 2086)

(NASA-Case-LEW-12245-1; US Patent-4,012,237;

US-Patent-Appl-SN-584094; US-Patent-Class-148-2;

US-Patent-Class-75-170; US-Patent-Class-148-12.7N;

US-Patent-Class-148-20.3; US-Patent-Class-148-32.5;

US-Patent-Class-148-162) Avail: US Patent Office CSCL 11F

An improved material for use in a catalytic reactor which reduces nitrogen oxide from internal combustion engines is in the form of a zirconium-modified, precipitation-strengthened nickel-copper alloy. This material has a nominal composition of Ni-30 Cu-0.2 Zr and is characterized by improved high temperature mechanical properties. Official Gazette of the U.S. Patent Office

**N77-20203\*** National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio.

# **THE NEW APPLICATIONS OF SPUTTERING AND ION PLATING**

Talivaldis Spalvins 1977 26 p refs Proposed for presentation at the Design Eng. Conf., Chicago, 9-12 May 1977; Sponsored by ASME

(NASA-TM-X-73551; E-8989) Avail: NTIS HC A03/MF A01 CSCL 11F

The potential industrial applications of sputtering and ion plating are strictly governed by the unique features these methods possess. The outstanding features of each method, the resultant coating characteristics and the various sputtering modes and configurations are discussed. New, more complex coatings and

deposits can be developed such as graded composition structures (metal-ceramic seals), laminated and dispersion strengthened composites which improve the mechanical properties and high temperature stability. Specific industrial areas where future effort of sputtering and ion plating will concentrate to develop intricate alloy or compound coatings and solve difficult problem areas are discussed.

Author

**N77-20204\*** National Aeronautics and Space Administration, Lewis Research Center, Cleveland, Ohio.

**FERROGRAPHIC ANALYSIS OF WEAR DEBRIS GENERATED IN A SLIDING ELASTOHYDRODYNAMIC CONTACT**  
William R. Jones, Jr., H. S. Nagarai (Ga. Inst. of Tech.), and Ward O. Winer (Ga. Inst. of Tech.) 1977 27 p refs Proposed for presentation at Ann. Meeting of the Am. Soc. of Lubrication Engrs., Montreal, 9-12 May 1977

(NASA-TM-X-73585; E-8925) Avail: NTIS HC A03/MF A01 CSCL 11F

The ferrograph was used to analyze wear debris generated in a sliding elastohydrodynamic contact. The amount of wear debris correlates well with the ratio of film thickness to composite surface roughness. Essentially all of the generated wear particles were of the normal rubbing wear type.

Author

**N77-20205\*** National Aeronautics and Space Administration, Lewis Research Center, Cleveland, Ohio.

**VOLATILE PRODUCTS IN THE CORROSION OF Cr, Mo, Ti AND FOUR SUPERALLOYS EXPOSED TO O<sub>2</sub> CONTAINING H<sub>2</sub>O AND GASEOUS NaCl**

George C. Fryburg, Robert A. Miller (NAS-NRC), Fred J. Kohl, and Carl A. Stearns 1977 21 p refs Proposed for presentation at the Symp. on Corrosion Probl. Involving Volatile Corrosion Products, Philadelphia, 8-13 May 1977; sponsored by Electrochem. Soc.

(NASA-TM-X-73599; E-9074) Avail: NTIS HC A02/MF A01 CSCL 11F

Cooled target collection techniques were used to study the formation of volatile products when samples of Cr, Ti, IN-738, 713C, NASA-TRW VIA and B-1900 were exposed, at elevated temperatures, to oxidizing environments containing H<sub>2</sub>O(g) and NaCl(g). Samples were heated to 1050 C in one atmosphere of slowly flowing oxygen, saturated with water at 21 C, and containing about 50 ppm NaCl(g). Volatile products were detected for all materials except B-1900 and Ti. High pressure mass spectrometric sampling was used to directly identify volatile products emanating from samples of Cr and IN-738 subject to the above environments.

Author

**N77-20206\*** National Aeronautics and Space Administration, Lewis Research Center, Cleveland, Ohio.

**SUPERCONDUCTIVITY IN SPUTTERED CuMo6S8**

Samuel Alterovitz, John A. Woodliff, Lee Kammerdiner, Huey-Lin Luo, and Christopher Martin 1977 14 p refs Presented at the Conf. on High Polymer Phys., San Diego, Calif., 20-24 Mar. 1977; sponsored by the Am. Phys. Soc.

(NASA-TM-X-73620; E-9083) Avail: NTIS HC A02/MF A01 CSCL 11F

Samples were prepared by melting the metals, followed by annealing to various temperatures. The result was a structurally weak material. Sputtered films on sapphire substrates were prepared and studied. The substrates give the films mechanical strength and permit easy attachment of electrical leads. Materials were characterized by X-ray diffraction, electron microscopy, electrical resistance vs. temperature, and critical current measurements. Some of the results on CuMo6S8 are presented.

Author

**N77-21216\*** National Aeronautics and Space Administration, Lewis Research Center, Cleveland, Ohio.

**SUSCEPTIBILITY TO HOT CORROSION OF FOUR NICKEL-BASE SUPERALLOYS, NASA-TRW VIA, B-1900, 713C AND IN-738**

Carl A. Stearns, Fred J. Kohl, and George C. Fryburg Apr. 1977 19 p refs  
(NASA-TN-D-8461; E-8977) Avail: NTIS HC A02/MF A01 CSCL 11F

The susceptibility to hot corrosion of four nickel-base, cast superalloys has been studied at 900 and 1000 C. The test consisted of coating alloy samples with known amounts of Na<sub>2</sub>SO<sub>4</sub> and oxidizing the coated samples isothermally in 1 atmosphere of slowly flowing oxygen, the weight-gain being monitored on a sensitive recording microbalance. Susceptibility to hot corrosion decreased in the order of decreasing molybdenum content of the alloys. Preoxidation of samples before hot-corrosion testing markedly increased the induction period observed prior to the inception of hot corrosion for all alloys tested. X-ray diffraction analyses of the oxide scales were made. All samples that underwent hot corrosion showed the presence of a (Ni,Co)MoO<sub>4</sub> layer near the alloy-oxide interface. Several specimens displayed resistance to hot corrosion and these showed NaTaO<sub>3</sub> as a prominent feature in their oxide scale. Our results may be interpreted as indicating that molybdenum in an alloy is detrimental, with respect to hot corrosion, while tantalum is beneficial.

Author

**N77-21217\*** National Aeronautics and Space Administration, Lewis Research Center, Cleveland, Ohio.

**REDUCED CHROMIUM STAINLESS STEEL ALLOYS Patent Application**

Joseph R. Stephens and Charles A. Barrett, inventors (to NASA) Filed 15 Apr. 1977 9 p  
(NASA-Case-LEW-12543-1; US-Patent-Appl-SN-788044) Avail: NTIS HC A02/MF A01 CSCL 11F

An austenitic stainless steel alloy is provided which contains reduced amounts of chromium as compared with stainless steels such as AISI Type 304 but whose oxidation resistance, corrosion resistance, strength and ductility are at least as good as those of such stainless steels. In a preferred embodiment, the alloy comprises, by weight percent, iron-12 chromium-10 nickel-2 aluminum-2 molybdenum-1.1 manganese-0.61 silicon-0.06 carbon. In a second preferred embodiment, the alloy comprises, by weight percent, iron-12 chromium-10 nickel-2.65 silicon-1.1 manganese-0.06 carbon.

NASA

**N77-22215\*** National Aeronautics and Space Administration, Lewis Research Center, Cleveland, Ohio.

**CARBURIZATION AND HEAT TREATMENT TO CAUSE CARBIDE PRECIPITATION IN GAMMA/GAMMA PRIME-DELTA EUTECTIC ALLOYS**

Surendra N. Tewari and Robert L. Dreshfield Washington, May 1977 19 p refs  
(NASA-TM-X-3518; E-8976) Avail: NTIS HC A02/MF A01 CSCL 11F

In an attempt to improve their longitudinal shear strength, several directionally solidified eutectic alloy compositions with minor element modifications were pact, carburized, and heat treated to provide selective carbide precipitation at the cell and grain boundaries. The directionally solidified Ni-17.8 Nb-6Cr-2.5Al-3Ta (weight percent) alloy was selected for the shear strength evaluation because it showed the shallowest delta-denuded zone at the carburized surface. The carburization-carbide precipitation treatment, however, did not appear to improve the longitudinal shear strength of the alloy.

Author

**N77-22216\*** National Aeronautics and Space Administration.  
Lewis Research Center, Cleveland, Ohio.

**X-RAY PHOTOELECTRON SPECTROSCOPIC STUDY OF SURFACE CHEMISTRY OF DIBENZYL-DISULFIDE ON STEEL UNDER MILD AND SEVERE WEAR CONDITIONS**  
Donald R. Wheeler Washington May 1977 18 p refs  
(NASA-TN-D-8460, E-8962) Avail NTIS HC A02/MF A01  
CSCL 11F

Wear tests were performed on 304 stainless steel lubricated with pure mineral oil with and without dibenzyl-disulfide. Both mild and severe wear were observed. The type of wear was distinguished by a marked change in wear rate, friction coefficient, and wear scar appearance. The chemical composition of the wear scar surface was examined with X-ray photoelectron spectroscopy in conjunction with argon ion sputter etching. In severe wear scars, a sulfide was formed at the expense of the normal oxide layer. In mild wear scars, there were only superficial sulfur compounds, but there was a substantial increase in the oxide thickness. Author

**N77-23238\*** National Aeronautics and Space Administration.  
Lewis Research Center, Cleveland, Ohio.

**VOLATILIZATION OF OXIDES DURING OXIDATION OF SOME SUPERALLOYS AT 1200 C**  
Isidor Zaplatynsky Washington Apr 1977 18 p refs  
(NASA-TN-D-8462, E-8978) Avail NTIS HC A02/MF A01  
CSCL 11F

Volatilization of oxides during cyclic oxidation of commercial Nichrome, Inconel 750, Rene 41, Stellite 6B, and GE-1541 was studied at 1200 C in static air. Quantitative analysis of oxide vapor deposits revealed that oxides of tungsten, molybdenum, niobium, manganese, and chromium volatilized preferentially from the oxide scales. Aluminum and silicon were not detected in vapor deposits. For all the alloys except GE-1541, chromium was found to be the main metallic element in the oxide scales. Author

**N77-23240\*** National Aeronautics and Space Administration.  
Lewis Research Center, Cleveland, Ohio.

**HIGH VELOCITY OXIDATION AND HOT CORROSION RESISTANCE OF SOME ODS ALLOYS**  
Carl E. Lowell and Daniel L. Deadmore Apr 1977 19 p refs  
(NASA-TM-X-73656, E-9172) Avail NTIS HC A02/MF A01  
CSCL 11F

Several oxide dispersion strengthened (ODS) alloys were tested for cyclic, high velocity, oxidation, and hot corrosion resistance. These results were compared to the resistance of an advanced, NiCrAl coated superalloy. An ODS FeCrAl were identified as having sufficient oxidation and hot corrosion resistance to allow potential use in an aircraft gas turbine without coating. Author

**N77-23241\*** National Aeronautics and Space Administration.  
Lewis Research Center, Cleveland, Ohio.

**OXIDATION AND CORROSION BEHAVIOR OF MODIFIED-COMPOSITION, LOW-CHROMIUM 304 STAINLESS STEEL ALLOYS**  
Joseph R. Stephens and Charles A. Barrett Washington May 1977 35 p refs  
(NASA-TN-D-8459, E-8872) Avail NTIS HC A03/MF A01  
CSCL 11F

The effects of substituting less strategic elements than Cr on the oxidation and corrosion resistance of AISI 304 stainless steel were investigated. Cyclic oxidation resistance was evaluated at 870 C. Corrosion resistance was determined by exposure of specimens to a boiling copper-rich solution of copper sulfate and sulfuric acid. Alloy substitutes for Cr included Al, Mn, Mo, Si, Ti, V, Y, and misch metal. A level of about 12% Cr was the minimum amount of Cr required for adequate oxidation and corrosion resistance in the modified composition 304 stainless steels. This represents a Cr saving of at least 33%. Two alloys containing 12% Cr and 2% Al plus 2% Mo and 12% Cr plus 2.65% Si were identified as most promising for more detailed evaluation. Author

**N77-24250\*** National Aeronautics and Space Administration.  
Lewis Research Center, Cleveland, Ohio.

**DIFFUSION WELDING OF A DIRECTIONALLY SOLIDIFIED GAMMA/GAMMA PRIME - DELTA EUTECTIC ALLOY**  
Thomas J. Moore May 1977 12 p refs  
(NASA-TM-X-3514, E-8755) Avail NTIS HC A02/MF A01  
CSCL 11F

Hot-press diffusion welding parameters were developed for a directionally solidified, gamma/gamma prime-delta eutectic alloy. Based on metallography, a good diffusion weld was achieved at 1100 C under 34.5 MPa (5 ksi) pressure for 1 hour. In addition, a dissimilar metal weld between gamma/gamma prime-delta and IN-100 was successfully made at 1100 C under 20.7 MPa (3 ksi) pressure for 1 hour. Author

**N77-24252\*** National Aeronautics and Space Administration.  
Lewis Research Center, Cleveland, Ohio.

**CREEP AND TENSILE PROPERTIES OF SEVERAL OXIDE-DISPERSION-STRENGTHENED NICKEL-BASE ALLOYS AT 1365 K**  
J. Daniel Wittenberger Washington May 1977 24 p refs  
(NASA-TN-D-8422, E-8882) Avail NTIS HC A02/MF A01  
CSCL 11F

The tensile properties at room temperature and at 1365 K and the tensile creep properties at low strain rates at 1365 K were measured for several oxide-dispersion-strengthened (ODS) alloys. The alloys examined included ODS Ni, ODS Ni-20Cr, and ODS Ni-16Cr-Al. Metallography of creep tested, large grain size ODS alloys indicated that creep of these alloys is an inhomogeneous process. All alloys appear to possess a threshold stress for creep. This threshold stress is believed to be associated with diffusional creep in the large grain size ODS alloys and normal dislocation motion in perfect single crystal (without transverse low angle boundaries) ODS alloys. Threshold stresses for large grain size ODS Ni-20Cr and Ni-16Cr-Al type alloys are dependent on the grain aspect ratio. Because of the deleterious effect of prior creep on room temperature mechanical properties of large grain size ODS alloys, it is speculated that the threshold stress may be the design limiting creep strength property. Author

**N77-24253\*** National Aeronautics and Space Administration.  
Lewis Research Center, Cleveland, Ohio.

**EFFECT OF SIMULATED EARTH REENTRY EXPOSURE ON MECHANICAL PROPERTIES OF SEVERAL OXIDE DISPERSION STRENGTHENED AND SUPERALLOY SHEET MATERIALS**

J. Daniel Whittenberger Washington May 1977 67 p refs  
(NASA-TN-D-8493, E-9062) Avail NTIS HC A04/MF A01  
CSCL 11F

The effects of simulated multiple reentry into the earth's atmosphere on the mechanical properties of several high temperature metallic sheet materials were evaluated. The materials included five tin-gage (nominally 0.025- or 0.037-cm) oxide dispersion strengthened (ODS) alloys and two tin-gage (nominally 0.037-cm) superalloys. Multiple reentry conditions were simulated through cyclic Plasma Arc Tunnel (PAT) exposure. PAT exposure generally consisted of 100 cycles of 600 second duration at 1255, 1366, or 1477 K in a Mach 4.6 airstream with an impact pressure of nominally 800 N/m<sup>2</sup>. PAT exposure generally produced a uniform oxide scale, oxide pits or intergranular oxidation, Kirkendall porosity, and alloy depletion zones except for the aluminum-containing ODS alloys. Only a uniform oxide scale was formed on the aluminum-containing ODS alloys. PAT exposure did not significantly affect the mechanical properties of the thin-gage (nominally 0.025- or 0.037-cm) alloys evaluated. Thus it appears that the microstructural changes produced by Plasma Arc Tunnel exposure has little influence on mechanical properties. Author



**N77-24254\*** National Aeronautics and Space Administration.  
Lewis Research Center, Cleveland, Ohio.

**HIGH TOUGHNESS-HIGH STRENGTH IRON ALLOY Patent Application**

J. R. Stephens and W. R. Witzke, inventors (to NASA) Filed 6 Jun. 1977 12 p  
(NASA-Case-Law-12542-1; US-Patent-Appl-SN-803822) Avail: NTIS HC A02/MF A01 CSCL 11F

A steel alloy is provided which exhibits excellent strength and toughness characteristics at cryogenic temperatures. The alloy consists essentially of about 10 to 16 percent by weight nickel, about 0.1 to 1.0 percent by weight aluminum, and 0 to about 3 percent by weight of at least one of the following additional elements: copper, lanthanum, niobium, tantalum, titanium, vanadium, yttrium, zirconium and the rare earth metals, with the balance being essentially iron. The steel alloy is produced by a process which includes using cold rolling at room temperature and subsequent heat treatment at temperatures ranging from 500 to 650 C, and possesses a fracture toughness ranging from 200 to 230 ksi and yield strengths up to 230 ksi NASA

condensation temperatures of sodium sulfate in flame environments. Deposits were collected on cylindrical platinum targets placed in the combustion products, and the deposition was studied as a function of collector temperature. Experimental deposition onset temperatures checked within experimental error with LTCE-predicted temperatures. A multicomponent mass transfer equation was developed to predict the rate of deposition of  $\text{Na}_2\text{SO}_4(\text{c})$  via vapor transport at temperatures below the deposition onset temperature. Agreement between maximum deposition rates predicted by this chemically frozen boundary layer (CFBL) theory and those obtained in the seeded laboratory burner experiments is good. Author

**N77-27215\*** National Aeronautics and Space Administration.  
Lewis Research Center, Cleveland, Ohio.

**HOT CORROSION RESISTANCE OF NICKEL-CHROMIUM-ALUMINUM ALLOYS**

Gilbert J. Santoro and Charles A. Barrett May 1977 35 p refs Presented at the 151st Meeting of the Electrochem. Soc., Philadelphia, 8-13 May 1977

(NASA-TM-73664) Avail: NTIS HC A03/MF A01 CSCL 11F

The hot corrosion resistance of nickel-chromium-aluminum alloy was examined by cyclically oxidizing sodium sulfate coated specimens in still air at 900, 1000 and 1100 C. The compositions tested were within the ternary region: Ni; Ni-50 at% Cr; and Ni-50 at% Al. At each temperature the corrosion data were statistically fitted to a third order regression equation as a function of chromium and aluminum contents. Corrosion isopleths were prepared from these equations. Compositional regions with the best hot corrosion resistance were identified. Author

**N77-26269\*** National Aeronautics and Space Administration.  
Lewis Research Center, Cleveland, Ohio.

**PLUGGING OF COOLING HOLES IN FILM-COOLED TURBINE VANES**

Daniel L. Deadmore and Carl E. Lowe 1977 23 p refs  
(NASA-TM-X-73661; E-9178) Avail: NTIS HC A02/MF A01 CSCL 11F

The plugging of vane cooling holes by impurities in a marine gas turbine was closely simulated in burner rig tests where dopants were added to the combustion products of a clean fuel (Jet-A). Hole plugging occurred when liquid phases, resulting from the dopants, were present in the combustion products. Increasing flame temperature and dopant concentration resulted in an increased rate of deposition and hole plugging. Author

**N77-26270\*** National Aeronautics and Space Administration.  
Lewis Research Center, Cleveland, Ohio.

**THERMOCHEMICAL ANALYSES OF THE OXIDATIVE VAPORIZATION OF METALS AND OXIDES BY OXYGEN MOLECULES AND ATOMS**

Fred J. Kohl, Denise M. Leisz, George C. Fryburg, and Carl A. Stearns 1977 25 p refs Presented at Symp. on Corrosion Problems Involving Volatile Corrosion Products, Philadelphia, 8-13 May 1977; sponsored by Electrochem. Soc.  
(NASA-TM-X-73682; E-9032) Avail: NTIS HC A02/MF A01 CSCL 11F

Equilibrium thermochemical analyses are employed to describe the vaporization processes of metals and metal oxides upon exposure to molecular and atomic oxygen. Specific analytic results for the chromium-, platinum-, aluminum-, and silicon-oxygen systems are presented. Maximum rates of oxidative vaporization predicted from the thermochemical considerations are compared with experimental results for chromium and platinum. The oxidative vaporization rates of chromium and platinum are considerably enhanced by oxygen atoms. Author

**N77-27214\*** National Aeronautics and Space Administration.  
Lewis Research Center, Cleveland, Ohio.

**THEORETICAL AND EXPERIMENTAL STUDIES OF THE DEPOSITION OF  $\text{Na}_2\text{SO}_4$  FROM SEEDED COMBUSTION GASES**

Fred J. Kohl, Gilbert J. Santoro, Carl A. Stearns, George C. Fryburg, and Daniel E. Rosner (Yale Univ.) 13 May 1977 29 p refs Presented at the Symp. on Corrosion Probl. Involving Volatile Corrosion Prod., Philadelphia, 8-13 May 1977; sponsored by the Electrochemical Society  
(NASA-TM-X-73683; E-9031) Avail: NTIS HC A03/MF A01 CSCL 21E

Flames in a Mach 0.3 atmospheric pressure laboratory burner rig were doped with sea salt,  $\text{Na}_2\text{SO}_4$ , and  $\text{NaCl}$ , respectively, in an effort to validate theoretical dew point predictions made by a local thermochemical equilibrium (LTCE) method of predicting

**N77-26265\*** National Aeronautics and Space Administration.  
Lewis Research Center, Cleveland, Ohio.

**BIMETALLIC JUNCTIONS Patent**

Frank G. Arcella (Westinghouse Corp., Pittsburgh), Gerald G. Lessmann (Westinghouse Corp., Pittsburgh), and Russell A. Lindberg, inventors (to NASA) Issued 5 Jul. 1977 5 p Filed 24 Oct. 1975 Supersedes N76-13267 (14 - 04, p 0429)  
(NASA-Case-LEW-11573-1; US-Patent-4,033,504; US-Patent-Appl-SN-625733; US-Patent-Class-228-190; US-Patent-Class-228-194; US-Patent-Class-228-232) Avail: US Patent Office CSCL 11F

The formation of voids through interdiffusion in bimetallic welded structures exposed to high operating temperatures is inhibited by utilizing an alloy of the parent materials in the junction of the parent materials or by preannealing the junction at an ultrahigh temperature. These methods are also used to reduce the concentration gradient of a hardening agent. Official Gazette of the U.S. Patent Office

**N77-26269\*** National Aeronautics and Space Administration.  
Lewis Research Center, Cleveland, Ohio.

**CRYOGENIC PROPERTIES OF A NEW TOUGH-STRONG IRON ALLOY**

Joseph R. Stephens and Walter R. Witzke Aug. 1977 13 p refs Presented at the 1977 Intern. Cryog. Mater. Conf., Boulder, Colo., 2-5 Aug. 1977  
(NASA-TM-73691; E-9226) Avail: NTIS HC A02/MF A01 CSCL 11D

A program was undertaken to develop an iron-base alloy having a fracture toughness of 220 MPa m superscript 1/2 with a corresponding yield stress of 1.4 GPa (200 ksi) at -196 C. An Fe-12Ni alloy was selected as the base alloy. Factors considered included reactive metal additions, effects of interstitial impurities, strengthening mechanisms, and weldability. The goals were met in an Fe-12Ni-0.5Al alloy strengthened by thermomechanical processing or by precipitate strengthening with 2 percent Cu. The alloy is weldable with the weld metal and heat affected zone in the postweld annealed condition having toughness equivalent to the base alloy. Author



**N77-31288\*** National Aeronautics and Space Administration.  
Lewis Research Center, Cleveland, Ohio.

**EFFECT OF HEATING METHOD ON STRESS-RUPTURE LIFE**

Peter T. Bizon and Frederick D. Calfo Jul. 1977 28 p refs  
(NASA-TM-73738; E-9208) Avail: NTIS HC A03/MF A02  
CSCS 11F

The effect of radiant(furnace), resistance(electric current), burner(hot gas stream), and a combination of resistance and burner heating on intermediate time (100 to 300 hr) stress-rupture life and reduction of area was evaluated. All heating methods were studied using the nickel-based alloy Udimet 700 while all but burner heating were evaluated with the cobalt-based alloy Mar-M 509. Limited test results of eight other superalloys were also included in this study. Resistance heated specimens had about 20 to 30 percent of the stress-rupture life of radiant heated specimens. The limited burner heating data showed about a 50 percent life reduction as compared to the radiant heated tests. A metallurgical examination gave no explanation for these reductions.

Author

**N77-32279\*** National Aeronautics and Space Administration.  
Lewis Research Center, Cleveland, Ohio

**DIRECTIONALLY SOLIDIFIED EUTECTIC GAMMA PLUS BETA NICKEL-BASE SUPERALLOYS Patent**

Melvin R. Jackson, inventor (to NASA) (GE, Schenectady, N.Y.)  
Issued 30 Aug. 1977 5 p Filed: 1 Jun. 1976 Sponsored by NASA

(NASA-Case-LEW-12906-1; US-Patent-4,045,255;

US-Patent-Appi-SN-691936; US-Patent-Class-148-32;

US-Patent-Class-75-170) Avail: US Patent Office CSCS 11F

A directionally solidified multivariant eutectic gamma - beta nickel-base superalloy casting having improved high temperature strength and oxidation resistance properties is provided. This comprises a two phase eutectic structure containing, on a weight percent basis, 5.0-15.0 tungsten, 8.5-14.5 aluminum, 0.0-35.0 cobalt and the balance being nickel. Embedded within the gamma phase nickel-base matrix are aligned eutectic beta phase (primarily (NiCo)Al) reinforcing lamellae.

Official Gazette of the U.S. Patent Office

**N77-32280\*** National Aeronautics and Space Administration  
Lewis Research Center, Cleveland, Ohio.

**NICKEL BASE ALLOY Patent**

John C. Freche and William J. Waters, inventors (to NASA)  
Issued 6 Sep. 1977 3 p Filed 30 Dec. 1975 Supersedes  
N76-14247 (14 - 05, p 0557)

(NASA-Case-LEW-12270-1; US-Patent-4,046,560;

US-Patent-Appi-SN-645507; US-Patent-Class-75-170;

US-Patent-Class-148-32.5) Avail: US Patent Office CSCS

11F

A nickel base superalloy for use at temperatures of 2000 F (1095 C) to 2200 F (1205 C) was developed for use as stator vane material in advanced gas turbine engines. The alloy has a nominal composition in weight percent of 18 tungsten, 7 aluminum, 1 molybdenum, 2 columbium, 0.3 zirconium, 0.2 carbon and the balance nickel.

Official Gazette of the U.S. Patent Office

**N77-32283\*** National Aeronautics and Space Administration.  
Lewis Research Center, Cleveland, Ohio.

**EFFECTS OF HEAT TREATING PM RENE' 95 SLIGHTLY BELOW THE GAMMA' SOLVUS**

Robert L. Dreshfield 1977 19 p refs Presented at the  
106th Ann Meeting of the Am. Inst. of Mining, Metallurgical,  
and Petrol Engr., Atlanta, 6-10 Mar. 1977  
(NASA-TM-X-73663; E-9183) Avail: NTIS HC A02/MF A01  
CSCS 11F

An investigation was performed on as-hot-isostatically-pressed (As HIP) Rene' 95 to obtain additional information on the variation of the amount of gamma prime with solutioning temperatures near the gamma prime solvus temperature and the resulting effects on tensile and stress rupture strength of As-HIP Rene' 95. The amount of gamma prime phase was found to increase at a rate of about 0.5% per degree Celsius as the temperature

decreased from the solvus temperature to about 50 C below the gamma prime solvus temperature. The change in the amount of gamma prime phase with decreasing solutioning temperature was observed to be primarily associated with decreasing solubilities of Al+Ti+Nb and increasing solubility of Cr in the gamma phase.

Author

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**EFFECT OF CARBON CONTENT ON FRICTION AND WEAR OF CAST IRONS**

Donald H. Buckley Sep. 1977 22 p refs

(NASA-TP-1052 E-9110) Avail: NTIS HC A02/MF A01 CSCS

11F

Friction and wear experiments were conducted with cast irons and wrought steels containing various amounts of carbon in the alloy structure in contact with 52100 steel. Gray cast irons were found to exhibit lower friction and wear characteristics than white cast irons. Further, gray cast iron wear was more sensitive to carbon content than was white. Wear with gray cast iron was linearly related to load, and friction was found to be sensitive to relative humidity and carbon content. The form, in which the carbon is present in the alloy, is more important, as the carbon content and no strong relationship seems to exist between hardness of these ferrous alloys and wear.

Author

**N77-32287\*** National Aeronautics and Space Administration.  
Lewis Research Center, Cleveland, Ohio.

**ROLLING-ELEMENT FATIGUE LIFE OF AMS 5749 CORROSION RESISTANT, HIGH TEMPERATURE BEARING STEEL**

Richard J. Parker and Robert S. Hodder (Latrobe Steel Co., Pa.)  
Oct. 1977 27 p refs Presented at 1977 Joint Lubrication

Conf., Kansas City, Mo., 3-5 Oct. 1977; Sponsored by Am. Soc. of Lubrication Engineering, and ASME

(NASA-TM-73698, E-9101) Avail: NTIS HC A03/MF A01

CSCS 11F

The rolling element fatigue lives of AMS 5749 and AISI M-50 were compared in tests run in the five ball fatigue tester and the rolling contact fatigue tester. The effects of double vacuum melting and retained austenite on the life of AMS 5749 were determined in five ball fatigue tests. The double vacuum melting process consisted of induction vacuum melting followed by vacuum arc remelting (VIM-VAR). In the five ball tests, VIM-VAR AMS 5749 gave lives at least six times that of VIM-VAR AISI M-50. Similar tests in the rolling contact fatigue tester showed

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**FERRNOGRAPHIC ANALYSIS OF WEAR DEBRIS GENERATED IN ACCELERATED ROLLING ELEMENT FATIGUE TESTS**

William R. Jones, Jr. and Richard J. Parker Oct. 1977 22 p refs Presented at Joint Lubrication Conf., Kansas City, Mo., 3-5 Oct. 1977; cosponsored by Am. Soc. of Lubrication Eng. and ASME

(NASA-TM-73715; E-9260) Avail: NTIS HC A02/MF A01  
CSCS 11F

The types and quantities of wear particles generated during accelerated ball rolling contact fatigue tests were determined. Ball specimens were made of AMS 5749, a corrosion resistant, high-temperature bearing steel. The lubricant was a super-refined naphthenic mineral oil. Conditions included a maximum Hertz stress of 5.215 times 10 to the 9th power Pa and a shaft speed of 10,000 rpm. Four types of wear particles were observed; normal rubbing wear particles, fatigue spall particles, spheres, and friction polymer.

Author

**N77-33313\*** National Aeronautics and Space Administration, Lewis Research Center, Cleveland, Ohio.

**BURNER RIG ALKALI SALT CORROSION OF SEVERAL HIGH TEMPERATURE ALLOYS**

D. Deadmore and C. Lowell 13 May 1977 20 p refs Presented at the 151st Meeting of the Electrochemical Soc., Inc., Philadelphia, 8-13 May 1977

(NASA-TM-X-73669; E-9176) Avail: NTIS HC A02/MF A01 CSCL 11F

The hot corrosion of five alloys was studied in cyclic tests in a Mach 0.3 burner rig into whose combustion chamber various aqueous salt solutions were injected. Three nickel-based alloys, a cobalt-base alloy, and an iron-base alloy were studied at temperatures of 700, 800, 900, and 1000 C with various salt concentrations and compositions. The relative resistance of the alloys to hot corrosion attack was found to vary with temperature and both concentration and composition of the injected salt solution. Results indicate that the corrosion of these alloys is a function of both the presence of salt condensed as a liquid on the surface and of the composition of the gas phases present.

Author

**N77-33316\*** National Aeronautics and Space Administration, Lewis Research Center, Cleveland, Ohio.

**THE 100,000-HOUR CYCLIC OXIDATION BEHAVIOR AT 815 C (1500 F) OF 33 HIGH-TEMPERATURE ALLOYS**

Charles A. Barnett 1977 9 p refs Presented at Environ. Effects and Degradation of Eng. Mater. Conf., Blacksburg, Va., 10-12 Oct. 1977; sponsored by Va. Polytech. Inst.

(NASA-TM-73707; E-9248) Avail: NTIS HC A02/MF A01 CSCL 11F

Commercial high-temperature Fe-, Ni-, and Co-base alloys were oxidized in air at 815C for ten 1000-hour cycles. Specific weight change versus time curves were derived and the 10,000-hour surface oxides were analyzed by X-ray diffraction. The alloys were ranked by a combination of appearance and mass loss estimates derived from gravimetric data.

Author

**A77-11561\*** Maintaining an elongated grain structure after deformation of mechanically alloyed NiCrAlY. D. M. Trella, T. K. Glasgow (Case-Western-Reserve University, Cleveland, Ohio), and L. J. Ebert (NASA, Lewis Research Center, Powder Metallurgy Section, Cleveland, Ohio). *Metallurgical Transactions A - Physical Metallurgy and Materials Science*, vol. 7A, Oct. 1976, p. 1593-1595. 5 refs. Grant No. NGR-36-003-094.

**A77-12204\*** Monitoring crack extension in fracture toughness tests by ultrasonics. S. J. Klima, D. M. Fisher, and R. J. Buzzard (NASA, Lewis Research Center, Cleveland, Ohio). *Journal of Testing and Evaluation*, vol. 4, Nov. 1976, p. 397-404. 9 refs.

An ultrasonic method was used to observe the onset of crack extension and to monitor continued crack growth in fracture toughness specimens during three-point bend tests. A 20-MHz transducer was used with commercially available equipment to detect average crack extension less than 0.09 mm. The material tested was a 300-grade maraging steel in the annealed condition. A crack extension resistance curve was developed to demonstrate the usefulness of the ultrasonic method for minimizing the number of tests required to generate such curves.

(Author)

**A77-15000\*** Growth kinetics of gamma-prime precipitates in a directionally solidified eutectic, gamma/gamma-prime-delta. S. N. Tewari (NASA, Lewis Research Center, Materials and Structures Div., Cleveland, Ohio). *Metallurgical Transactions A - Physical Metallurgy and Materials Science*, vol. 7A, Aug. 1976, p. 1237-1239. 10 refs.

A directionally solidified eutectic alloy (DSEA), of those viewed as potential candidates for the next generation of aircraft gas turbine blade materials, is studied for the gamma-prime growth kinetics, in

the system (Ni-Nb-Cr-Al), specifically: Ni-20 w/o Nb-6 w/o Cr-2.5 w/o Al gamma/gamma-prime-delta DSEA. Heat treatment, polishing and etching, and preparation for electron micrography are described, and the size distribution of gamma-prime phase following various anneals is plotted, along with gamma-prime growth kinetics in this specific DSEA, and the cube of gamma-prime particle size vs anneal time. Activation energies and coarsening kinetics are studied.

R.D.V.

**A77-17056\*** Dissolution kinetics of small amounts of oxygen in tantalum alloy T-111 and internal oxide displacement reactions during annealing. S. Stecura (NASA, Lewis Research Center, Cleveland, Ohio). *Oxidation of Metals*, vol. 10, Oct. 1976, p. 291-309. 35 refs.

Oxygen was added to T-111 (Ta-8W-2Hf, wt. %) at 820 and 990 C at an oxygen pressure of about 0.0003 torr. The technique employed permitted predetermined and reproducible doping of T-111 up to 3.0 at. % oxygen. Based on the temperature dependence of the doping reaction, it is concluded that the initial rates of oxygen pickup are probably controlled by solution of oxygen into the T-111 lattice. Although hafnium oxides are more stable than those of tantalum or tungsten, analyses of extracted residues indicate that the latter oxides predominate in the as-doped specimens, presumably because of the higher concentrations of tantalum and tungsten in the alloy. However, high-temperature annealing promotes gettering of dissolved oxygen and of other oxides to form hafnium oxides. Small amounts of tantalum and tungsten oxides were still present after high-temperature annealing. Tungsten oxide (WO<sub>3</sub>) volatilizes slightly from the surface of T-111 at 990 C. The vaporization of WO<sub>3</sub> has no apparent effect on the doping reaction.

(Author)  
DATA SUMMARY: Study of the doping reaction of T-111 alloy with oxygen at doping temperatures of 820 and 990 C and the distribution of oxygen in the doped condition as well as after annealing at 1320 C for 2 hr; variables are impurity concentration, doping temperature, doping time, annealing temperature, weight gain, oxygen count, oxygen concentration, diamond prism hardness, distance from sample surface, residue content. X-ray diffraction spacing; 5 figures and 5 tables include numeric data.

**A77-18494\*** Effects of alloy composition in alleviating embrittlement problems associated with the tantalum alloy T-111. R. Stephens (NASA, Lewis Research Center, Cleveland, Ohio). *Journal of the Less Common Metals*, vol. 51, Jan. 1977, p. 93-111. 15 refs.

The causes of aging embrittlement in T-111 (Ta-8W-2Hf) and the effects of alloy modification were investigated. Results showed that T-111 contains a critical combination of tungsten and hafnium that leads to loss of ductility at 196 C after aging near 1040 C. This appears to occur because tungsten enhances hafnium segregation to grain boundaries and thus also leads to increased susceptibility to hydrogen embrittlement. Aging embrittlement was not observed in tantalum alloys with reduced tungsten or hafnium contents; however, most of the alloys studied have lower strength than T-111 and exhibit susceptibility to hydrogen embrittlement.

(Author)  
DATA SUMMARY: The effects of pre-age annealing temperature in the range 1650-1980 C and of aging temperature in the range 925-1150 C on the bend ductility of alloy specimens are examined; variables are aging time, aging temperature, annealing temperature, oxygen content, nitrogen content, hydrogen content, bend ductility, ultimate tensile stress, and lower yield stress. seven figures and two tables include numeric data.

**A77-20236\*** Discussion of 'Unusual potential drop during the application of the electrical potential method in a fracture mechanics test' by V. Bachmann and D. Munz. J. L. Shannon, Jr. (NASA, Lewis Research Center, Cleveland, Ohio). *Journal of Testing and Evaluation*, vol. 4, Nov. 1976, p. 425.

DATA SUMMARY: No numeric data are presented.

**A77-21039 \*** Effect of thermal cycling on the microstructure of a directionally solidified Fe, Cr, Al-TaC eutectic alloy. F. H. Harf (NASA, Lewis Research Center, Cleveland, Ohio) and S. N. Tewari, *Metallurgical Transactions A - Physical Metallurgy and Materials Science*, vol. 8A, Jan. 1977, p. 202, 203, 7 refs.

Cylindrical bars (1.2 cm diameter) of Fe-13.6Cr-3.7Al-9TaC (wt %) eutectic alloy were directionally solidified in a modified Bridgman type furnace at 1 cm/h. The alloy microstructure consisted of aligned TaC fibers imbedded in a bcc Fe-Cr-Al matrix. Specimens of the alloy were thermally cycled from 1100 to 425 C in a burner rig. The effects of 1800 thermal cycles on the microstructure was examined by scanning electron microscopy, revealing a zig-zag shape of TaC fibers aligned parallel to the growth direction. The mechanism of carbide solution and reprecipitation on the (111) easy growth planes, suggested previously to account for the development of irregular serrations in Co-Cr-Ni matrix alloys, is believed to be responsible for these zig-zag surfaces. B.J.

DATA SUMMARY: No numeric data are presented.

**A77-21399 \*** Recrystallization as a controlling process in the wear of some f.c.c. metals. R. C. Bill and D. Wisander (NASA, Lewis Research Center, Seals Section, Cleveland, Ohio). *Wear*, vol. 41, Feb. 1977, p. 351-363, 15 refs.

Detailed examination of copper specimens after sliding against 440 C steel in liquid methane at speeds up to 25 m/s and loads of up to 2 kg showed the metal comprising the wear surface to possess a fine cell recrystallized structure. Wear proceeded by the plastic shearing of metal in this near surface region without the occurrence of visible metal transfer. A dynamic balance between the intense shear process at the surface and the nucleation of recrystallized grains was proposed to account for the behavior of the metal at the wear surface. Sliding wear experiments were also conducted on Ag, Cu-10% Al, Cu-10% Sn, Ni and Al. It was found that low wear and the absence of heavy metal transfer were associated with those metals observed to undergo recrystallization nucleation without prior recovery. (Author)

DATA SUMMARY: The wear rate of copper is studied as a function of normal load and also as a function of sliding velocity; variables are wear rate, normal load, sliding velocity, layer thickness, wear volume, and stacking fault energy; two figures and two tables include numeric data.

**A77-21620 \*** Metal powder reactions in ball milling. A. Arias (NASA, Lewis Research Center, Cleveland, Ohio). *I & EC - Industrial and Engineering Chemistry, Product Research and Development*, vol. 15, June 1976, p. 142-152, 5 refs.

On milling chromium powder in three metal chlorides and either chromium or nickel powders in ten organic liquids representative of nine different functional groups, the powders always reacted with the liquids and became contaminated with elements from them. The milled powders had specific surface areas ranging from 0.14 to 37 sq m/g, and the total contamination with elements from the milling liquid ranged from 0.01 to 56 wt%. In most milling runs, compounds resulting from substitution, addition, or elimination reactions formed in or from the milling liquid, and in most runs with organic liquids H<sub>2</sub>, CH<sub>4</sub>, and CO<sub>2</sub> were generated. (Author)

DATA SUMMARY: Diverse data are presented; variables include percent powder recovered, solid-phase O<sub>2</sub> concentration, solid-phase C concentration, solid-phase H<sub>2</sub> concentration, powder surface, total pressure increase in ball mill during run, milling time, gas-phase H<sub>2</sub> concentration, gas-phase CH<sub>4</sub> concentration, gas-phase CO<sub>2</sub> concentration.

**A77-23239 \*** Effects of C and Hf concentration on phase relations and microstructure of a wrought powder-metallurgy superalloy. R. V. Miner, Jr. (NASA, Lewis Research Center, Cleveland, Ohio). *Metallurgical Transactions A - Physical Metallurgy and Materials Science*, vol. 8A, Feb. 1977, p. 259-263, 10 refs.

NASA 118-11, a candidate alloy for advanced temperature turbine engine disks, and four modifications with varying C and Hf

concentrations were produced from prealloyed powders. Several notable effects of C and Hf concentration in the alloys were observed. Both the amount of the gamma-prime phase and its solvus temperature increased with decreasing C, but only the gamma-prime solvus was affected by Hf, increasing with increasing Hf. Hf also promoted a cellular gamma-prime precipitation. Hf was, however, about equally distributed between gamma-prime and gamma. Hf and C both affected the carbides formed. Increasing both promoted formation of an MC relative to that of an M<sub>6</sub>C. (Author)

DATA SUMMARY: Gamma-prime solvus temperatures are studied as a function of C and Hf concentrations; variables are concentration, phase content, and gamma-prime solvus temperature; four figures and two tables include numeric data.

**A77-26393 \*** Low vapor pressure braze alloys for thermionic energy converters. V. L. Bair (NASA, Lewis Research Center, Cleveland, Ohio). *Institute of Electrical and Electronics Engineers, International Conference on Plasma Science, Austin, Tex., May 24-26, 1976, Paper*, 10 p. 6 refs.

Preliminary results in the use of some low-vapor-pressure braze alloys are reported; these are binary alloys of refractory metals (Ti, Zr, Hf, Ru, Nb, Ir, Mo, Ta, Os, Re, W) with vapor pressures below 0.1 nanotorr at 1500 K or 10 microrr at 2000 K. The melting point minima or eutectics of the alloys range from 1510 K to above 3000 K. Melting points and surface wetting on a Ta base are given. Results are presented on brazing of Ir, LaB<sub>6</sub>, Nb, Re, W, and ZrO<sub>2</sub> (with 22 wt % Zr) into a Ta base or a Nb-1% Zr base. The results are applicable in electrode screening programs for thermionic cesium diodes. R.D.V.

DATA SUMMARY: A Knoop microhardness and composition analysis is presented for the braze materials used; variables are melting point, apparent brazing temperature, Knoop microhardness, and chemical composition; three tables include numeric data.

**A77-26397 \*** Estimation of conjugate gamma and gamma-prime compositions in Ni-base superalloys. R. L. Dreshfield (NASA, Lewis Research Center, Cleveland, Ohio). *National Bureau of Standards, Workshop on Applications of Phase Diagrams in Metallurgy and Ceramics, Gaithersburg, Md., Jan. 10-12, 1977, Paper*, 29 p. 32 refs.

To control the formation of unwanted phases, superalloy metallurgists have developed methods of estimating the composition of the matrix phase of alloys. That composition is then used to estimate the alloy's propensity toward sigma and other unwanted phase formations upon prolonged exposure to elevated temperatures in service. This paper reviews two approaches for estimating phase composition from the melt composition. One method is based on assigning essentially fixed stoichiometry to precipitating phases and is typified by 'PHACOMP'. The second method uses analytical geometry to interpret phase diagrams and is shown to be applicable to a two-phase region of a six-component Ni-base system. The geometric method is also shown to be applicable to commercial Ni-base superalloys. (Author)

DATA SUMMARY: Diverse data are presented; variables include alloy composition, amount of alloying addition, amount of gamma prime phase, gamma-phase coefficient, gamma-prime-phase coefficient, Ni-Al-Cr-Ti phase diagram at 750 C, Ni-Cr-Al phase diagram at 750 C, Ni-Cr-Al phase diagram at 850 C, Ni-Cr-Ti phase diagram at 750 C, Ni-Ti-Al phase diagram at 750 C.

**A77-28707 \*** Weldability of high toughness Fe-12% Ni alloys containing Ti, Al or Nb. J. H. Devletian (Youngstown State University, Youngstown, Ohio), J. R. Stephens, and W. R. Witzke (NASA, Lewis Research Center, Cleveland, Ohio). (*American Welding Society, Annual Meeting, 58th, Philadelphia, Pa., Apr. 25-28, 1977*) *Welding Journal, Research Supplement*, vol. 56, Apr. 1977, p. 97-s to 103-s, 7 refs. Research supported by the American Society for Engineering Education and NASA.

Three exceptionally high-toughness Fe-12%Ni alloys designed

for cryogenic service were welded using the GTA welding process. Evaluation of weldability included equivalent energy (Kied) fracture toughness tests, transverse-weld tensile tests at -196 and 25 C and weld crack sensitivity tests. The Fe-12%Ni-0.25%Ti alloy proved extremely weldable for cryogenic applications, having weld and HAZ properties comparable with those of the wrought base alloy. The Fe-12%Ni-0.5%Al had good weld properties only after the weld joint was heat treated. The Fe-12%Ni-0.25%Nb alloy was not considered weldable for cryogenic use because of its poor weld joint properties at -196 C and its susceptibility to hot cracking. (Author)

**A77-29859 \*** Thermal-stress fatigue behavior of twenty-six superalloys. P. T. Bizon (NASA, Lewis Research Center, Cleveland, Ohio) and D. A. Spera. In: Thermal fatigue of materials and components; Proceedings of the Symposium, New Orleans, La., November 17, 18, 1975. (A77-29852 12-26) Philadelphia, Pa., American Society for Testing and Materials, 1976, p. 106-122. 17 refs.

The comparative thermal-stress fatigue resistances of 26 nickel- and cobalt-base alloys were determined by fluidized bed tests. Cycles to cracking differed by almost three orders of magnitude for these materials, with directional solidification and surface protection showing definite benefit. The alloy-coating combination with the highest thermal-stress fatigue resistance was directionally solidified NASA TAZ-8A with an RT-SP coating. Its oxidation resistance was also excellent, showing approximately a 1/2 percent weight loss after 14,000 fluidized bed cycles. (Author)

**A77-33105 \*** Stress rupture resistance. J. C. Freche (NASA, Lewis Research Center, Materials and Structures Div., Cleveland, Ohio). In: Alloy and microstructural design (A77-33101 14-26) New York, Academic Press, Inc., 1976, p. 145-173. 29 refs.

Principles underlying the design of metallic systems for stress rupture resistance are outlined by considering the specific case studies of cobalt and nickel-base superalloys. Ways in which superalloys can be designed for high stress rupture resistance are discussed. In describing the alloying procedures, the strengthening mechanisms involved and methods of avoiding phases detrimental to stress rupture resistance are identified. New processing techniques such as controlled solidification, prealloyed powder processing, and autoclave heat treatments are described as further means of achieving increased stress rupture resistance in superalloy and other systems.

S.D

**A77-33176 \*** Effects of long-term aging on ductility and microstructure of Cb and Mo alloys. J. R. Stephens (NASA, Lewis Research Center, Cleveland, Ohio). *Metallography*, vol. 10, 1977, p. 1-25. 10 refs.

A program was conducted to determine if aging embrittlement occurs in columbium-base alloys C-103, Cb-12r, and Cb-752 or in a molybdenum alloy, Mo-TZM. Results showed that aging embrittlement does not occur in C-103, Cb-12r, or Mo-TZM during long-term (1000 hour) aging at temperatures in the range of 700-1025 C. In comparison, aging embrittlement occurred in the Cb-752 alloy after similar aging at 900 C. A critical combination of the solute additions W and Zr led to Zr segregation at grain boundaries during long-term aging which subsequently resulted in embrittlement as indicated by an increase in the ductile-brittle transition temperature from below -196 C to about -150 C. (Author)

**A77-33389 \*** Potential structural material problems in a hydrogen energy system. H. R. Gray (NASA, Lewis Research Center, Cleveland, Ohio), H. G. Nelson (NASA, Ames Research Center, Moffett Field, Calif.), R. E. Johnson (NASA, Johnson Space Center, Houston, Tex.), W. B. McPherson (NASA, Marshall Space Flight Center, Huntsville, Ala.), F. S. Howard (NASA, Kennedy Space Center, Cocoa Beach, Fla.), and J. H. Swisher (ERDA, Washington,

D.C.). In: World Hydrogen Energy Conference, 1st, Miami Beach, Fla., March 1-3, 1976, Proceedings. Volume 2. (A77-33326 14-44) Coral Gables, Fla., University of Miami, New York, Pergamon Press, 1976, p. 98-15 to 98-39. 40 refs.

Potential structural material problems that may be encountered in the three components of a hydrogen energy system - production, transmission/storage, and utilization - have been identified. Hydrogen embrittlement, corrosion, oxidation, and erosion may occur during the production of hydrogen. Hydrogen embrittlement is of major concern during both transmission and utilization of hydrogen. Specific materials research and development programs necessary to support a hydrogen energy system are described. An awareness of probable shortages of strategic materials has been maintained in these suggested programs. (Author)

**A77-35952 \*** Fretting of AISI 9310 and selected fretting resistant surface treatments. R. C. Bill (NASA, Lewis Research Center, Cleveland, Ohio). *American Society of Lubrication Engineers, Annual Meeting, 32nd, Montreal, Canada, May 9-12, 1977, Paper 23 p. 16 refs.*

Fretting wear experiments were conducted with uncoated AISI 9310 mating surfaces, and with combinations incorporating a selected coating to one of the mating surfaces. Wear measurements and SEM observations indicated that surface fatigue, as made evident by spallation and surface crack formation, is an important mechanism in promoting fretting wear to uncoated 9310. Increasing humidity resulted in accelerated fretting, and a very noticeable difference in nature of the fretting debris. Of the coatings evaluated, aluminum bronze with a polyester additive was most effective at reducing wear and minimizing fretting damage to the mating uncoated surface, by means of a self lubricating film that developed on the fretting surfaces. Chromium plate performed as an effective protective coating, itself resisting fretting and not accelerating damage to the uncoated surface. (Author)

**A77-36099 \*** The effect of delta T /oxidizing temperature minus cooling temperature/ on oxide spallation. D. L. Deadmore and C. E. Lowell (NASA, Lewis Research Center, Cleveland, Ohio). *Oxidation of Metals*, vol. 11, Apr. 1977, p. 91-106. 12 refs.

Several alloys (one iron base and five nickel base) were cyclically oxidized in a series of tests in which the higher temperature (1100 or 1200 C) of the cycle was fixed at a level to allow ample oxidation in reasonable time and the lower temperature was variable to allow cycle temperature differences of up to 1400 C. For all nickel alloys, as delta T increased the extent of spallation increased. This effect was attributed to thermal expansion mismatches between the oxide and the nickel substrate. The FeCrAl alloy was not sensitive to delta T and resisted spalling at delta T levels to 1400 C. FeCrAl, and the Al2O3 scale which forms on it, have thermal expansion coefficients which are substantially more alike than any of the other oxide-metal combinations tested. (Author)

**A77-37875 \*** Toward more environmentally resistant gas turbines - Progress in NASA-Lewis programs. C. E. Lowell, S. J. Grisaffe, and S. R. Levine (NASA, Lewis Research Center, Cleveland, Ohio). *Conference on Gas Turbine Materials in a Marine Environment, 3rd, Bath, England, Sept. 20-23, 1976, Paper, 23 p. 15 refs.*

The paper surveys programs for improving the environmental resistance of gas turbine and power system materials to oxidation and hot corrosion. A computer program Corst has been produced which provides an initial method for predicting long-time metal loss using short-time oxidation data. The role of the coefficient of thermal expansion mismatch on oxide spallation is being studied. A parabolic oxidation attack model in conjunction with regression analysis of weight change data has been applied to the study of oxidation and hot corrosion attack of some Ni-Cr-Al system alloys. Oxide-dispersion strengthened alloys based on the Ni-Cr-Al system are being developed. Sodium sulfate formation during turbine combustion is being investigated from a thermodynamic viewpoint. M.L.

**A77-38371 \*** Mechanism of beneficial effect of tantalum in hot corrosion of nickel-base superalloys. G. C. Fryburg, C. A. Stearns, and F. J. Kohl (NASA, Lewis Research Center, Cleveland, Ohio). *Electrochemical Society, Journal*, vol. 124, July 1977, p. 1147, 1148.

X-ray diffraction and electron microprobe analyses were used to examine a prominent NaTaO<sub>3</sub> pattern formed in a number of nickel-base superalloys. It is found that a beneficial effect of tantalum with respect to hot corrosion attack arises from the ability of Ta<sub>2</sub>O<sub>5</sub> to tie up Na<sub>2</sub>O and prevent the formation of a molten Na<sub>2</sub>MoO<sub>4</sub> phase. B.J.

**A77-38822 \*** Application of Strainrange Partitioning to the prediction of creep-fatigue lives of AISI Types 304 and 316 stainless steel. J. F. Saltzman and G. R. Halford (NASA, Lewis Research Center, Cleveland, Ohio). (*American Society of Mechanical Engineers, Conference on Petroleum Mechanical Engineering and Pressure Vessels and Piping, Mexico City, Mexico, Sept. 19-24, 1976, Paper 76-PVR 26*) *ASME Transactions, Series J: Journal of Pressure Vessel Technology*, vol. 99, May 1977, p. 264-271. 16 refs.

As a demonstration of the predictive capabilities of the method of Strainrange Partitioning, published high temperature, low cycle, creep-fatigue test results on AISI Types 304 and 316 stainless steel were analyzed and calculated cyclic lives compared with observed lives. Predicted lives agreed with observed lives within factors of two for 76 percent, factors of three for 93 percent, and factors of four for 98 percent of the laboratory tests analyzed. Agreement between observed and predicted lives is judged satisfactory considering that the data are associated with a number of variables (two alloys, several heats and heat treatments, a range of temperatures, different testing techniques, etc.) that are not directly accounted for in the calculations. (Author)

**A77-40032 \*** Hot corrosion studies of four nickel-base superalloys: B-1900, NASA-TRW V1A, 713C and IN738. G. C. Fryburg, F. J. Kohl, and C. A. Stearns (NASA, Lewis Research Center, Cleveland, Ohio). In: *Symposium on Properties of High Temperature Alloys with Emphasis on Environmental Effects*, Las Vegas, Nev., October 17-22, 1976, Proceedings. (A77-40012 18-26) Princeton, N.J., Electrochemical Society, Inc., 1976, p. 585-594. 7 refs.

The susceptibility to hot corrosion of four nickel-base superalloys has been studied at 900 and 1000 C in one atmosphere of slowly flowing oxygen. Hot corrosion was induced by coating the samples with known doses of Na<sub>2</sub>SO<sub>4</sub> and oxidizing the coated samples isothermally on a sensitive microbalance. In order of decreasing susceptibility to hot corrosion, these alloys were ranked B-1900, 713C, NASA-TRW V1A, IN738. This order corresponds to the order of decreasing molybdenum content of the alloys. Chemical evidence for B-1900 indicates that hot corrosion is instigated by acid fluxing of the protective Al<sub>2</sub>O<sub>3</sub> coating by MoO<sub>3</sub>. (Author)

**A77-42461 \*** Creep and tensile properties of several oxide dispersion strengthened nickel base alloys. J. D. Whittenberger (NASA, Lewis Research Center, Cleveland, Ohio). *Metallurgical Transactions A - Physical Metallurgy and Materials Science*, vol. 8A, July 1977, p. 1155-1163. 21 refs.

The creep properties at 1365 K of several oxide dispersion strengthened (ODS) alloys were studied, where the creep exposures involved low strains, on the order of 1% or less, after nominally 100 hours of testing. It was found that ODS alloys possess threshold stresses for creep. Creep in polycrystalline ODS alloys is an inhomogeneous process. The threshold stresses in large grain size ODS Ni-20Cr and Ni-16Cr-4.5Al type alloys are dependent on the grain aspect ratio. P.T.H.

**A77-46725 \*** Resistance of Ni-Cr-Al alloys to cyclic oxidation at 1100 and 1200 C. C. A. Barrett and C. E. Lowell (NASA, Lewis Research Center, Cleveland, Ohio). *Oxidation of Metals*, vol. 11, Aug. 1977, p. 199-223. 11 refs.

**A77-47047 \*** Application of strainrange partitioning to the prediction of MPC creep-fatigue data for 2 1/4 Cr-1 Mo steel. J. F. Saltzman and G. R. Halford (NASA, Lewis Research Center, Cleveland, Ohio). In: *Symposium on Creep-Fatigue Interaction*, New York, N.Y., December 5-10, 1976, Proceedings. (A77-47042 22-26) New York, American Society of Mechanical Engineers, 1976, p. 283-298. 18 refs.

Creep-fatigue tests were conducted on annealed 2.25Cr-1Mo steel in air at 538 C involving interspersed of rapid strain cycles (0 to 22 cycles) between constant tensile stress-hold periods (23 or 47 hours). Life predictions were made on the basis of the strain range-life relations obtained from short-time material characterization tests on tubular specimens taken from the same heat as the specimens for the creep-fatigue tests. The creep-fatigue tests lasted from about 500 to 5000 hours, while the short-time tests used as the prediction basis lasted from 0.1 to 100 hours. By partitioning the creep and plastic strains within every cycle and summing the damage on a cycle-by-cycle basis, the predicted lives agreed with the observed ones within factors of two. P.T.H.

**A77-47048 \*** Treatment of multiaxial creep-fatigue by strainrange partitioning. S. S. Manson (Case-Western Reserve University, Cleveland, Ohio) and G. R. Halford (NASA, Lewis Research Center, Cleveland, Ohio). In: *Symposium on Creep-Fatigue Interaction*, New York, N.Y., December 5-10, 1976, Proceedings. (A77-47042 22-26) New York, American Society of Mechanical Engineers, 1976, p. 299-322. 13 refs.

The paper investigates some basic concepts and their application for extending the strain-range partitioning method for treating elevated-temperature creep-fatigue interactions from uniaxial to multiaxial situations. The problem is restricted to initiation of an engineering-size crack and to proportional loading. The basic parameters are the Mises-Hencky equivalent stress and strain, and a rule is formulated for choosing the sign of the dominant principal direction. Creep and plastic ratchet strains can also be taken into account. The interaction damage rule is formulated. An application to hold-time tests in torsion illustrates the use of the rules developed. P.T.H.

**A77-48696 \*** Volatile products in the corrosion of Cr, Mo, Ti and four superalloys exposed to O<sub>2</sub> containing H<sub>2</sub>O and gaseous NaCl. G. C. Fryburg, R. A. Miller, F. J. Kohl, and C. A. Stearns (NASA, Lewis Research Center, Cleveland, Ohio). *Electrochemical Society, Symposium on Corrosion Problems Involving Volatile Corrosion Products*, Philadelphia, Pa., May 12, 1977, Paper. 20 p. 20 refs.

**A77-48697 \*** Hot corrosion resistance of nickel-chromium-aluminum alloys. G. J. Santoro and C. A. Barrett (NASA, Lewis Research Center, Cleveland, Ohio). *Electrochemical Society, Meeting*, 151st, Philadelphia, Pa., May 8-13, 1977, Paper. 34 p. 12 refs.

The hot corrosion resistance of nickel-chromium-aluminum alloys was examined by cyclically oxidizing sodium sulfate-coated specimens in still air at 900, 1000, and 1100 C. The compositions tested were within the ternary region: Ni, Ni-50 at.% Cr, and Ni-50 at.% Al. At each temperature the corrosion data were statistically fitted to a third order regression equation as a function of chromium and aluminum contents. From these equations corrosion isopleths were prepared. Compositional regions with the best hot corrosion resistance were identified. (Author)

**A77-51583 \*** # Sharply notch cylindrical tension specimen for screening plane-strain fracture toughness. I - Influence of fundamental testing variables on notch strength. II - Applications in aluminum alloy quality assurance of fracture toughness. M. H. Jones, R. T. Bubsey, W. F. Brown, Jr. (NASA, Lewis Research Center, Fracture Branch, Cleveland, Ohio), R. J. Bucci, S. F. Collis, R. F. Kohm, and J. G. Kaufman (Aluminum Company of America, Alcoa Laboratories, Alcoa Center, Pa.). In: Developments in fracture mechanics test methods standardization; Proceedings of the Symposium, St. Louis, Mo., May 4, 1976. (A77-51576 24-39) Philadelphia, Pa., American Society for Testing and Materials, 1977, p. 115-152, 14 refs.

A description is presented of studies which have been conducted to establish an improved technology base for a use of the sharply notched cylindrical specimen in quality assurance tests of aluminum alloy products. The results are presented of an investigation of fundamental variables associated with specimen preparation and testing, taking into account the influence of the notch root radius, the eccentricity of loading, the specimen diameter, and the notch depth on the sharp notch strength. Attention is given to the statistical procedures which are necessary to establish correlations between the sharp notch strength and the plane-strain fracture toughness for high-strength aluminum alloys. G.R.

**N77-11154\*# Pratt and Whitney Aircraft, East Hartford, Conn. REFINEMENT OF PROMISING COATING COMPOSITIONS FOR DIRECTIONALLY CAST EUTECTICS**

T. E. Strangman, E. J. Felten, and R. S. Bendon Oct 1976 158 p refs

(Contract NAS3-18920)

(NASA-CR-135103, TWA-5441)

Avail. NTIS

HC A08/MF A01 CSCL 11C

The successful application of high creep strength, directionally solidified gamma/gamma prime-delta (Ni-19.7Cr-6Cr-2.5Al) eutectic superalloy turbine blades requires the development of suitable coatings for airfoil, root and internal blade surfaces. In order to improve coatings for the gamma/gamma prime-delta alloy, the current investigation had the goals of (1) refining promising coating compositions for directionally solidified eutectics, (2) evaluating the effects of coating/substrate interactions on the mechanical properties of the alloy, and (3) evaluating diffusion aluminide coatings for internal surfaces. Burner rig cyclic oxidation, furnace cyclic hot corrosion, ductility, and thermal fatigue tests indicated that NiCrAlY + Pt63 to 127 micron Ni-18Cr-12Al-0.3Y + 6 micron Pt and NiCrAlY(63 to 127 micron Ni-18Cr-12Al-0.3Y) coatings are capable of protecting high temperature gas path surfaces of eutectic alloy airfoils. Burner rig (Mach 0.37) testing indicated that the useful coating life of the 127 micron thick coatings exceeded 1000 hours at 1366 K (2000 deg F) isothermal fatigue and furnace hot corrosion tests indicated that 63 micron NiCrAlY, NiCrAlY + Pt and platinum modified diffusion aluminide (Pt + Al) coating systems are capable of protecting the relatively cooler surfaces of the blade root. Finally, a gas phase coating process was evaluated for diffusion aluminizing internal surfaces and cooling holes of air-cooled gamma/gamma prime-delta turbine blades. Author

**N77-12181\*# Battelle Pacific Northwest Labs., Richland, Wash. DEVELOPMENT OF SPUTTERED HIGH TEMPERATURE COATINGS FOR THRUST CHAMBERS Final Report**

R. Busch and M. A. Bayne 9 Aug. 1976 25 p

(Contract NAS3-19721)

(NASA-CR-135097) Avail. NTIS HC A02/MF A01 CSCL 11F

Adherent insulating coatings were developed for thrust chamber service. The coatings consisted of nickel and a ceramic, and were graded in composition from pure nickel at the thrust chamber wall to pure ceramic at the coating surface. The coatings were deposited by rf sputtering from a target with a reversed composition gradient, which was produced by plasma spraying powder mixtures. The effect of deposition parameters on coating characteristics and adherence is discussed. Author

**N77-12182\*# TRW Systems Group, Redondo Beach, Calif.**

**HEAT PIPE MATERIALS COMPATIBILITY Final Report**

J. E. Eninger, G. L. Fleischman, and E. E. Luedke Jan. 1976 46 p refs

(Contract NAS3-19128)

(NASA-CR-135069; TRW-26148-6004-RU-00) Avail. NTIS HC A04/MF A01 CSCL 11F

An experimental program to evaluate noncondensable gas generation in ammonia heat pipes was completed. A total of 37 heat pipes made of aluminum, stainless steel and combinations of these materials were processed by various techniques, operated at different temperatures and tested at low temperature to quantitatively determine gas generation rates. In order of increasing stability are aluminum/stainless combination, all aluminum and all stainless heat pipes. One interesting result is the identification of intentionally introduced water in the ammonia during a reflux step as a means of surface passivation to reduce gas generation in stainless-steel/aluminum heat pipes. Author

**N77-18160\*# Carnegie-Mellon Univ., Pittsburgh, Pa. Inst. of Research.**

**EVALUATION OF THE MECHANICAL PROPERTIES OF ELECTROSLAG REFINED IRON ALLOYS**

G. K. Bhat Dec. 1976 103 p refs

(Contract NAS3-18929)

(NASA-CR-135044) Avail. NTIS HC A06/MF A01 CSCL 11F

Nitronic 40 (21Cr-6Ni-9Mn), HY-130, 9Ni-4Co, and D-6 alloys were prepared and evaluated in the form of 15.2 mm thick plates. Smooth bar tensile tests, double-edge sharp notch fracture toughness tests, Charpy V-notch impact tests were conducted on appropriate heat treated specimens of the four steel plates at 22 C, 50 C, 100 C, 150 C, and 196 C. Similar material characterization, including metallographic evaluation studies on air melt and vacuum arc melt grades of same four alloy steels were conducted for comparative purposes. A cost analysis of manufacturing plates of air melt, electroslag remelt and vacuum arc remelt grades was performed. The results of both material characterization and cost analyses pointed out certain special benefits of electroslag processing iron base alloys. Author

**DATA SUMMARY** Diverse data are presented, variables include stress, temperature, impact energy, tensile strength, yield strength, elongation, reduction of area, loads, fracture strength stress intensity, costs

**N77-20207\*# Lockheed California Co., Burbank**

**FRACTURE CONTROL OF H-O ENGINE COMPONENTS Final Report, 17 Jun. 1974 - 6 Aug. 1976**

J. T. Ryder Feb. 1977 489 p refs Prepared in cooperation with General Dynamics/Convair, San Diego, Calif., International Harvester, Chicago, and the Ladish Co., Cudahy, Wis

(Contract NAS3-18896)

(NASA-CR-135137, LR-27810)

Avail. NTIS

HC A21/MF A01 CSCL 11F

An investigation was made to obtain the material characterization and fatigue crack propagation data necessary to establish the salient characteristics of a Ti-6Al-2.5Sn(ELI) alloy fuel pump impeller to be used in a cryogenic service environment. Testing variables considered were: coupon orientation, frequency, load range ratio, and temperature. Data analysis correlated crack propagation data from conventional laboratory coupons with data from a parallel sided rotating disk used to model rotor stresses. Four major design recommendations when bore regions of fuel pump impellers to be operated in cryogenic environments are to be relatively highly stressed are discussed. Author

**N77-20208\*# Cyclops Corp., Bridgeville, Pa. Specialty Steel Div.**

**DEVELOPMENT OF AN EXTRA-HIGH STRENGTH POWDER METALLURGY NICKEL-BASE SUPERALLOY Final Report**

W. B. Kent Jan. 1977 67 p refs

(Contract NAS3-16795)

(NASA-CR-135131; U-C-R-1173) Avail: NTIS  
HC A04/MF A01 CSCL 11F

A program was conducted to optimize the composition of NASA 11b-11, an alloy originally developed as a wrought material, for thermal stability and to determine the feasibility for producing the alloy using powder metallurgy techniques. Seven compositions were melted and atomized, hot isostatically pressed, cross rolled to disks and heat treated. Tensile and stress rupture properties from room temperature to 870 C (1600 F) were determined in addition to thermal stability characteristics. Processing variables included hot isostatic pressing parameters and handling, cross rolling procedures and heat treatment cycles. NASA 11b-11 displayed the best combination of overall properties for service as a 760 C (1400 F) disk material. Its composition is 0.06 C, 8.5 Cr, 9.0 Co, 2.0 Mo, 7.1 W, 6.6 Ta, 4.5 Al, 0.75 Ti, 0.5 V, 0.7 Hf, 0.01 B, 0.05 Zr and balance Ni. While the alloy exhibits the highest 760 C (1400 F) rupture strength reported for any powder metallurgy disk alloy to date, additional studies to further evaluate the effects of heat treatment may be required. The alloy is not susceptible to topologically close-packed phase formation during thermal exposure at 870 C (1600 F) for 1,500 hours, but its mechanical property levels are lowered due to grain boundary carbide formation. Author

**N77-21215\*** Carnegie-Mellon Univ., Pittsburgh, Pa. Dept. of Metallurgy and Materials Science  
**INVESTIGATION OF THE FRACTURE MECHANISM IN Ti-5Al-2.5Sn AT CRYOGENIC TEMPERATURES** Final Report  
R. H. VanStone, J. R. Low, Jr., and J. L. Shannon, Jr. Apr. 1977 112 p refs  
(Contract NGR-39-087-047)  
(NASA-CR-135120; CMU-NASA-3Ti) Avail: NTIS  
HC A06/MF A01 CSCL 11F

The influence of microstructure on the fracture mechanism and plane-strain fracture toughness of Ti-5Al-2.5Sn was studied through the use of fractography and metallographic sectioning techniques. One-inch thick plates of extra low interstitial (ELI) and normal interstitial Ti-5Al-2.5Sn were mill annealed at 815 C followed by either air or furnace cooling. These variations in composition and cooling rate resulted in differences in the volume fraction and internal structure of the non-stabilized phase and in the crystallographic texture and ordering of the alpha matrix. The tensile properties of these plates were determined at 20 K, 77 K, and 295 K. The air-cooled ELI plate was the toughest material evaluated. Author

**N77-22213\*** International Nickel Co. Inc. Suffern, N. Y. Paul D. Merica Research Lab.  
**DEVELOPMENT OF OXIDE DISPERSION STRENGTHENED TURBINE BLADE ALLOY BY MECHANICAL ALLOYING**  
H. F. Merrick, L. R. Curwick, and Y. G. Kim. Jan. 1977 69 p refs  
(Contract NAS3-19694)  
(NASA-CR-135150) Avail: NTIS HC A04/MF A01 CSCL 11F

There were three nickel-base alloys containing up to 18 wt % of refractory metal examined initially for oxide dispersion strengthening. To provide greater processing freedom, however, a leaner alloy was finally selected. This base alloy, alloy D, contained 0.05C/15Cr/2Mo/4W/2Ta/4.5Al/2Ti/0.15Zr/0.01B/Bal Ni. Following alloy selection, the effect of extrusion, heat treatment, and oxide volume fraction and size on microstructure and properties were examined. The optimum structure was achieved in zone annealed alloy D which contained 2.5 vol % of 35 nm Y2O3 and which was extruded 16:1 at 1038 C. Author

**N77-22214\*** TRW, Inc., Cleveland, Ohio  
**STRAIN PARTITIONING OF THREE ALLOYS IN ULTRAHIGH VACUUM USING THE STEP STRESS METHOD** Final Report, 14 May - 14 Nov. 1976  
C. S. Kortovich. Apr. 1977 49 p refs

(Contract NAS3-20103)

(NASA-CR-135187; TRW-ER-7926) Avail: NTIS  
HC A03/MF A01 CSCL 11F

The ultrahigh vacuum strain controlled thermal-mechanical strain cycling fatigue behavior of ASTAR 811C, 304 stainless steel and A-286 was studied. The step stress procedure of experimental strainrange partitioning was utilized to partition the inelastic strainranges for tests duplicating conditionings previously reported by TRW. An analytical method is described in which these partitioned inelastic strainrange data can be used to develop the four basic life relationships for these materials. Author

**N77-28268\*** Martin Marietta Corp., Denver, Colo.  
**ENVIRONMENTAL EFFECTS ON ALUMINUM FRACTURE**  
Fred R. Schwartzberg and John A. Shepic. Aug. 1976 63 p refs

(Contract NAS3-18923)  
(NASA-CR-135182; MCR 76-385) Avail: NTIS  
HC A04/MF A01 CSCL 11F

The sustained load stress corrosion cracking (SCC) threshold for aluminum alloy 214 was determined using smooth (sigma sub TH) and precracked (K sub ISCC) specimens and cyclic load growth behavior in 3.5% NaCl salt solution was studied. The relationship between K sub ISCC and sigma sub TH was also studied. The work showed that 2124-T851 aluminum alloy in plate gage has a moderately high resistance to stress corrosion attack. Experimental results showed that no SCC occurred in the longitudinal and long transverse directions in any of the tests. Some SCC was found by smooth tests in the short transverse direction, and the data were confirmed by two test methods: sigma sub TH 275 MN/sq m (40 ksi). No SCC was found from compact specimen tests in any direction, surface flaw and center notch specimens evaluated in the short transverse direction exhibited SCC. The data indicate that stress corrosion behavior is defect, size, and stress dependent, but not entirely in accordance with a stress intensity controlled mechanism. Author

**N77-33314\*** Syracuse Univ., N. Y. George Sachs Fracture and Fatigue Research Lab.  
**FATIGUE CRACK GROWTH AT ELEVATED TEMPERATURE 316 STAINLESS STEEL AND H-13 STEEL**

Wan Ching Chen and H. W. Lu. [1976] 56 p refs  
(Grant NGR 33-022-157)  
(NASA-CR-135105; MTS-HWL-4116-776) Avail: NTIS  
HC A04/MF A01 CSCL 11F

Crack growths were measured at elevated temperatures under four types of loading: pp, pc, cp, and cc. In H-13 steel, all these four types of loading gave nearly the same crack growth rates and the length of hold time had negligible effects. In AISI 316 stainless steel, the hold time effects on crack growth rate were negligible if the loading was tension-tension type, however these effects were significant in reversed bending load, and the crack growth rates under these four types of loading varied considerably. Both tensile and compressive hold times caused increased crack growth rate but the compressive hold period was more deleterious than the tensile one. Metallographic examination showed that all the crack paths under different types of loading were largely transgranular for both CTS tension-tension specimens and SEN reversed cantilever bending specimens. In addition, an electric potential technique was used to monitor crack growth at elevated temperature. Author

**A77-29863\*** Vacuum thermal-mechanical fatigue behavior of two iron-base alloys. K. D. Sheffield (United Technologies Materials Engineering and Research Laboratory, East Hartford, Conn.), in: Thermal fatigue of materials and components; Proceedings of the Symposium, New Orleans, La., November 17, 18, 1975. (A77-29852 12-261 Philadelphia, Pa.: American Society for Testing and Materials, 1976, p. 214-226. Contract No. NAS3-6010.)

The present study extends the concept of in-phase grain boundary ratcheting to two iron base alloys (Type 304 stainless steel and A286 alloy) and provides a clearer interpretation of out-of-phase

grain boundary ratcheting effects observed in the A286 alloy which does not exhibit geometric instability. Elevated-temperature low-cycle thermal-mechanical fatigue tests in an ion-pumped ultrahigh vacuum chamber revealed significant effects of frequency and combined temperature-strain cycling on fatigue life. In-phase thermal cycling (tension at high temperature and compression at low temperature) caused large life reductions in both materials due to grain boundary cavitation caused by unreversed grain boundary sliding (grain boundary ratcheting). Out-of-phase thermal cycling (tension at low temperature and compression at high temperature) also caused large cyclic life reductions in both materials. In the A286 alloy, out-of-phase life reductions are attributed to compressive ratcheting.

S.D.

laboratory air environments in the temperature range 538-871 C. Elevated-temperature, compressive-strain hold-time experiments were also conducted. In hydrogen, the cyclic stress-strain behavior of both materials at 538 C was characterized by appreciable cyclic hardening at all strain ranges. At 871 C neither material hardened significantly, in fact, at 5% strain range 347 steel showed continuous cyclic softening until failure. The fatigue resistance of 347 steel was slightly higher than that of Alloy X at all temperatures and strain ranges. Ten-minute compressive hold time experiments at 760 and 871 C resulted in increased fatigue lives for 347 steel and decreased fatigue lives for Alloy X. Both alloys showed slightly lower fatigue resistance in air than in hydrogen. Some fractographic and metallographic results are also given.

P.T.H.

**A77-37874 \*** "Coatings for directional eutectics. J. R. Rearden and M. R. Jackson (GE Metallurgy Laboratory, Schenectady, N.Y.). Conference on Gas Turbine Materials in a Marine Environment, 3rd, Bath, England, Sept. 20-23, 1976, Paper. 10 p. 12 refs. Contracts No. NAS3-16793; No. NAS3-17815. (GE-R76CRD257)

Coatings developed to provide oxidation protection for the directionally-solidified eutectic alloy NiTaC-B (4.4 weight percent Cr) were evaluated. Of seven Co-, Fe- and Ni-base coatings that were initially investigated, best resistance to cyclic oxidation was demonstrated by duplex coatings fabricated by depositing a layer of NiCrAlY by vacuum evaporation from an electron beam source followed by deposition of an Al overlayer using the pack cementation process. It was found that addition of carbon to the coating alloy substantially eliminated the problem of fiber denudation in TaC-type eutectic alloys. Burner rig cycled NiTaC-B samples coated with Ni-20Cr-5Al-0.1C-0.1Y+Al and rupture-tested at 1100 deg C performed as well as or better than uncoated, vacuum cycled and air-tested NiTaC-B; however, a slight degradation with respect to uncoated material was noted in air-stress rupture tests at 870 deg C for both cycled and uncycled samples.

C.K.D.

**A77-45496 \*** "High temperature oxidation resistant coatings for the directionally solidified Ni-Nb-Cr-Al eutectic superalloy. T. E. Strangman, N. E. Ulion (United Technologies Co p., Pratt and Whitney Aircraft Group, East Hartford, Conn.), and E. J. Felten. (American Ceramic Society. Annual Meeting, 78th, Cincinnati, Ohio, May 4, 1976, Paper 17-C-76.) American Ceramic Society Bulletin, vol. 56, Aug. 1977, p. 700-705. 25 refs. Contracts No. NAS3-16792; No. NAS3-18920.

Protective coatings required for the Ni-Nb-Cr-Al directionally solidified eutectic superalloy were developed and evaluated on the basis of oxidation resistance, diffusional stability, thermal fatigue, and creep resistance. NiCrAlY+Pt and NiCrAlY physical vapor-deposition coating systems exhibited the best combination of properties. Burner-rig testing indicated that the useful life of a 127-micron-thick NiCrAlY+Pt coating exceeds 1000 h at 1366 K. Eutectic-alloy creep lives at 1311 K and a stress of 151.7 MN/sq m were greater for NiCrAlY+Pt-coated specimens than for uncoated specimens by a factor of two.

(Author)

**A77-47044 \*** "Low-cycle fatigue of two austenitic alloys in hydrogen gas and air at elevated temperatures. C. E. Jaske and R. C. Rice (Battelle Columbus Laboratories, Columbus, Ohio). In: Symposium on Creep-Fatigue Interaction, New York, N.Y., December 5-10, 1976, Proceedings. (A77-47042 22-26) New York, American Society of Mechanical Engineers, 1976, p. 101-128. 20 refs. Research supported by the Aerojet Nuclear Systems Co.; Contract No. NAS3-20078.

The low-cycle fatigue resistance of type 347 stainless steel and Hastelloy Alloy X was evaluated in constant-amplitude, strain-controlled fatigue tests conducted under continuous negative strain cycling at a constant strain rate of 0.001 per sec and at total axial strain ranges of 1.5, 3.0, and 5.0 percent in both hydrogen gas and



## 27 NONMETALLIC MATERIALS

Includes physical, chemical, and mechanical properties of plastics, elastomers, lubricants, polymers, textiles, adhesives, and ceramic materials.

**N77-10199\*** National Aeronautics and Space Administration, Lewis Research Center, Cleveland, Ohio.

### **GASEOUS EMISSIONS AND TOXIC HAZARDS ASSOCIATED WITH PLASTICS IN FIRE SITUATIONS: A LITERATURE REVIEW**

Thomas L. Junod. Oct. 1976. 67 p. refs.  
(NASA-TN-D-8338; E-8549) Avail. NTIS HC A04/MF A01 CSCL 111

The hazards of plastics in fire situations, the gases emitted, the factors influencing the nature of these emissions, the characteristics of toxic gases, and the results of laboratory studies, are discussed. The literature pertaining to the pyrolysis and oxidation of plastics was reviewed. An effort was made to define the state of the art for determining the toxic gases emitted by plastics under fire conditions. Recommendations are made and research needs defined as a result of this review. Author

**N77-10200\*** National Aeronautics and Space Administration, Lewis Research Center, Cleveland, Ohio.

### **NONELASTOMERIC ROD SEALS FOR ADVANCED HYDRAULIC SYSTEMS**

William F. Hady and Alvin W. Waterman. 1976. 25 p. refs.  
Presented at A-6 Meeting on Aerospace Fluid Power and Control Technologies, Las Vegas, Nev., 4-8 Oct. 1976; sponsored by SAE.  
(NASA-TM-X-73525; E-8940) Avail. NTIS HC A02/MF A01 CSCL 111

Advanced high temperature hydraulic system rod sealing requirements can be met by using seals made of nonelastomeric (plastic) materials in applications where elastomers do not have adequate life. Exploratory seal designs were optimized for advanced applications using machinable polyimide materials. These seals demonstrated equivalent flight hour lives of 12,500 at 350 F and 9,875 at 400 F in advanced hydraulic system simulation. Successful operation was also attained under simulated space shuttle applications, 96 reentry thermal cycles and 1,438 hours of vacuum storage. Tests of less expensive molded plastic seals indicated a need for improved materials to provide equivalent performance to the machined seals. Author

**N77-11175\*** National Aeronautics and Space Administration, Lewis Research Center, Cleveland, Ohio.

### **EVALUATION OF POTASSIUM TITANATE AS A COMPONENT OF ALKALINE FUEL CELL MATRICES**

Robert E. Post. Washington. Nov. 1976. 27 p. refs.  
(NASA-TN-D-8341; E-8174) Avail. NTIS HC A03/MF A01 CSCL 10A

Various forms of potassium titanate were found to have almost complete resistance to chemical attack in 45 wt % KOH at 150 C (423 K) for up to 9600 hours. Electron microscopy and X-ray diffraction disclosed important differences with respect to lability and stability. The octatitanate appeared to possess the best combination of properties. It was concluded that potassium titanate could be produced in a more asbestos-like form. Fiber dispersion is important in matrix manufacture. Author

**N77-18170\*** National Aeronautics and Space Administration, Lewis Research Center, Cleveland, Ohio.

### **ADHESION AND FRICTION OF IRON AND GOLD IN CONTACT WITH ELEMENTAL SEMICONDUCTORS**

Donald H. Buckley and William A. Brainard. Washington. Jan. 1977. 21 p. refs.  
(NASA-TN-D-8394; E-8903) Avail. NTIS HC A02/MF A01 CSCL 11F

Adhesion and friction experiments were conducted with single crystals of iron and gold in contact with single crystals of

germanium and silicon. Surfaces were examined in the sputter cleaned state and in the presence of oxygen and a lubricant. All experiments were conducted at room temperature with loads of 1 to 50 grams, and sliding friction was at a sliding velocity of 0.7 mm/min. Results indicate that the friction nature of metals in contact with semiconductors is sensitive to orientation, that strong adhesion of metals to both germanium and silicon occurs, and that friction is lower with silicon than with germanium for the same orientation. Surface effects are highly sensitive to environment. Silicon, for example, behaves in an entirely brittle manner in the clean state, but in the presence of a lubricant the surface deforms plastically. Author

**DATA SUMMARY:** Orientation, doping, and surface film effects on metal-semiconductor bonding contact; variables include friction coefficients, sliding friction, crystal surfaces, doped crystals, adhesive bonding, crystal dislocations, and loads. 8 figures and no tables are included.

**N77-17239\*** National Aeronautics and Space Administration, Lewis Research Center, Cleveland, Ohio.

### **THERMAL BARRIER COATINGS: A NEAR TERM, HIGH PAYOFF TECHNOLOGY**

S. R. Levine and J. S. Clark. 1977. 15 p. refs. Presented at the Workshop on Ceramics for Energy Conversion Systems, Orlando, Fla., 24-26 Jan. 1977; sponsored by ERDA. Prepared in cooperation with US Army Air Mobility R and D Lab., Cleveland.  
(NASA-TM-X-73586; E-9049) Avail. NTIS HC A02/MF A01 CSCL 11B

The present status of thermal barrier coatings is reviewed including both experimental results and forecasts of the benefits derived from use of these coatings in aircraft and utility gas turbines. The potential of thermal barrier coatings relative to structural ceramics is discussed along with a development plan for these coatings. Author

**DATA SUMMARY:** Performance of various oxide ceramic thermal barrier layers; variables include cycles to failure, leading-edge wall temperature, coolant-to-gas flow ratio, time, weight change, thermodynamic efficiency, and specific output. 4 figures and 1 table include numeric.

**N77-17240\*** National Aeronautics and Space Administration, Lewis Research Center, Cleveland, Ohio.

### **OPPORTUNITIES FOR CERAMICS IN THE ERDA/NASA CONTINUOUS COMBUSTION PROPULSION SYSTEMS PROGRAM**

Charles P. Blankenship and Robert B. Schulz (ERDA, Washington, D.C.). 1977. 6 p. refs. Presented at the Workshop on Ceramics for Energy Conversion Systems, Orlando, Fla., 24-27 Jan. 1977; sponsored by ERDA.  
(NASA-TM-X-73597; E-9071) Avail. NTIS HC A02/MF A01 CSCL 11B

An overview on engine development projects for potential use of ceramics is reported. A major ceramics materials technology effort is described to meet anticipated engine system requirements in terms of the automotive application, some of the more pressing technology needs, and some indications of how to conduct this technology program with industry-engine development projects focus on both gas turbine and Stirling engines. Author

**N77-19253\*** National Aeronautics and Space Administration, Lewis Research Center, Cleveland, Ohio.

### **EFFECT OF ION-PLATED FILMS OF GERMANIUM AND SILICON ON FRICTION, WEAR, AND OXIDATION OF 52100 BEARING STEEL**

Donald H. Buckley and Talivaldis Spalvins. Mar. 1977. 11 p. refs.  
(NASA-TN-D-8436; E-8953) Avail. NTIS HC A02/MF A01 CSCL 11G

Friction and wear experiments were conducted with ion plated films of germanium and silicon on the surface of 52100 bearing steel both dry and in the presence of mineral oil. Both silicon

and germanium were found to reduce wear, with germanium being more effective than silicon. An optimum film thickness of germanium for minimum wear without surface crack formation was found to be approximately 400 nanometers (4000 Å). The presence of silicon and germanium on the 52100 bearing steel surface improved resistance to oxidation. Author

**DATA SUMMARY:** Ion plated metal lubricant films for reducing bearing steel wear: the variables include coefficient of friction, film thickness, rider wear, silicon films, germanium films, and sliding velocity. 3 figures and no tables.

**N77-32312\*** National Aeronautics and Space Administration, Lewis Research Center, Cleveland, Ohio.

**FRICITION AND WEAR BEHAVIOR OF SINGLE-CRYSTAL SILICON CARBIDE IN CONTACT WITH TITANIUM**

Kazuhiro Miyoshi and Donald H. Buckley Sep. 1977 24 p refs

(NASA-TP-1035; E-9067) Avail: NTIS HC A02/MF A01 CSCL 11G

Sliding friction experiments were conducted with single crystal silicon carbide in sliding contact with titanium. Results indicate that the friction coefficient is greater in vacuum than in argon and that this is due to the greater adhesion or adhesive transfer in vacuum. Thin films of silicon carbide transferred to titanium also adhered to silicon carbide both in argon at atmospheric pressure and in high vacuum. Cohesive bonds fractured on both the silicon carbide and titanium surfaces. The wear debris of silicon carbide created by fracture plowed the silicon carbide surface in a plastic manner. The friction characteristics of titanium in contact with silicon carbide were sensitive to the surface roughness of silicon carbide, and the friction coefficients were higher for a rough surface of silicon carbide than for a smooth one. The difference in friction results was due to plastic deformation (plowing of titanium). Author

**N77-33346\*** National Aeronautics and Space Administration, Lewis Research Center, Cleveland, Ohio.

**X-RAY PHOTOELECTRON SPECTROSCOPY STUDY OF RADIOFREQUENCY-SPUTTERED TITANIUM CARBIDE, MOLYBDENUM CARBIDE, AND TITANIUM BORIDE COATINGS AND THEIR FRICTION PROPERTIES**

William A. Brainerd and Donald R. Wheeler Oct. 1977 21 p refs

(NASA-TP-1033; E-9102) Avail: NTIS HC A02/MF A01 CSCL 11G

Radiofrequency sputtered coatings of titanium carbide, molybdenum carbide and titanium boride were tested as wear resistant coatings on stainless steel in a pin on disk apparatus. X-ray photoelectron spectroscopy (XPS) was used to analyze the sputtered films with regard to both bulk and interface composition in order to obtain maximum film performance. Significant improvements in friction behavior were obtained when properly biased films were deposited on deliberately preoxidized substrates. XPS depth profile data showed thick graded interfaces for bias deposited films even when adherence was poor. The addition of 10 percent hydrogen to the sputtering gas produced coatings with thin poorly adherent interfaces. Results suggest that some of the common practices in the field of sputtering may be detrimental to achieving maximum adherence and optimum composition for these refractory compounds. Author

**N77-33350\*** National Aeronautics and Space Administration, Lewis Research Center, Cleveland, Ohio.

**FRICITION AND DEFORMATION BEHAVIOR OF SINGLE-CRYSTAL SILICON CARBIDE**

Kazuhiro Miyoshi (Kanazawa Univ., Kanazawa, Japan) and Donald H. Buckley Oct. 1977 22 p refs

(NASA-TP-1053; E-9121) Avail: NTIS HC A02/MF A01 CSCL 20B

Friction and deformation studies were conducted with single-crystal silicon carbide in sliding contact with diamond. When the radius of curvature of the spherical diamond rider

was large (0.3), deformation of silicon carbide was primarily elastic. Under these conditions the friction coefficient was low and did not show a dependence on the silicon carbide orientation. Further, there was no detectable cracking of the silicon carbide surfaces. When smaller radii of curvature of the spherical diamond riders (0.15 and 0.02 mm) or a conical diamond rider was used, plastic grooving occurred and the silicon carbide exhibited anisotropic friction and deformation behavior. Under these conditions the friction coefficient depended on load. Anisotropic friction and deformation of the basal plane of silicon carbide was controlled by the slip system  $[1010]-1120$  and cleavage off  $[1010]$ . Author

**N77-33351\*** National Aeronautics and Space Administration, Lewis Research Center, Cleveland, Ohio.

**FUNDAMENTAL CONSIDERATIONS FOR FUTURE SOLID LUBRICANTS**

R. L. Johnson and H. E. Stiney 11 Sep. 1969 32 p refs Presented at Conf. on Solid Lubricants, Kansas City, Mo. 9-11 Sep. 1969; sponsored by AFML and Midwest Res. Inst. (NASA-TM-X-52659; E-5241) Avail: NTIS HC A03/MF A01 CSCL 11H

Properties important to the performance of solid lubricants are discussed. Those properties include shear characteristics, coherence between particles, resistance to cold flow, adherence to the substrate, applicable chemical thermodynamics and kinetics of materials and environments, polymorphism, and rheology. The following generalizations are made: (1) chemical thermodynamics and kinetics are powerful tools for use in determining the useful environments and methods of application for solid film lubricants; (2) the primary requirement for a solid lubricant is low shear strength; (3) the rheology of solid film constituents and formulations is likely to be of vital importance to performance and life; and (4) adherence and mobility of surface films is another primary requirement for long lived solid lubricants. Author

**A77-11194\*** Friction and transfer behavior of pyrolytic boron nitride in contact with various metals. D. H. Buckley (NASA, Lewis Research Center, Cleveland, Ohio). *American Society of Lubrication Engineers and American Society of Mechanical Engineers, Lubrication Conference, Boston, Mass., Oct. 5-7, 1976, ASLE Preprint 76-LC-18-2*. 6 p. 6 refs.

Sliding friction experiments were conducted with pyrolytic boron nitride in sliding contact with itself and various metals. Auger emission spectroscopy was used to monitor transfer of pyrolytic boron nitride to metals and metals to pyrolytic boron nitride. Results indicate that the friction coefficient, for pyrolytic boron nitride in contact with metals can be related to the chemical activity of the metals and more particularly to the valence bond character of the metal. Transfer was found to occur to all metals except silver and gold and the amount of transfer was less in the presence than in the absence of metal oxide. Friction was less for pyrolytic boron nitride in contact with a metal in air than in vacuum. (Author)

**A77-11198\*** Effect of atmosphere and temperature on wear, friction, and transfer of polyimide films. R. L. Fusaro (NASA, Lewis Research Center, Cleveland, Ohio). *American Society of Lubrication Engineers and American Society of Mechanical Engineers, Lubrication Conference, Boston, Mass., Oct. 5-7, 1976, ASLE Preprint 76-LC-18-1*. 8 p. 23 refs.

Friction and wear experiments conducted on polyimide films bonded to 440 C stainless steel disks indicated that a wear transition (from high wear to low wear) accompanied the friction transition (from high friction to low friction). The transition was found to be atmospheric dependent as well as temperature dependent. Wear rate calculations indicated that, at temperatures above the transition, wear could be up to 600 times less than at temperatures below the transition. Transfer to metallic riders was also investigated and found to be considerably different at temperatures above and below the transition. (Author)

**A77-22985 \*** Ion-beam-sputter modification of the surface morphology of biological implants. A. J. Weigand and B. A. Banks (NASA, Lewis Research Center, Cleveland, Ohio). (*American Vacuum Society, National Vacuum Symposium, 23rd, Chicago, Ill., Sept. 21-24, 1976.*) *Journal of Vacuum Science and Technology*, vol. 14, Jan.-Feb. 1977, p. 326-331. 14 refs.

The surface chemistry and texture of materials used for biological implants may significantly influence their performance and biocompatibility. Recent interest in the microscopic control of implant surface texture has led to the evaluation of ion-beam sputtering as a potentially useful surface roughening technique. Ion sources, similar to electron-bombardment ion thrusters designed for propulsive applications, are used to roughen the surfaces of various biocompatible alloys or polymer materials. These materials are typically used for dental implants, orthopedic prostheses, vascular prostheses, and artificial heart components. Masking techniques and resulting surface textures are described along with progress concerning evaluation of the biological response to the ion-beam-sputtered surfaces.

(Author)

DATA SUMMARY: No numeric data are presented.

**A77-24865 \*** Pressure sintering of  $\text{Si}_3\text{N}_4\text{-Al}_2\text{O}_3$  /Sialon/. H. C. Yeh (Cleveland State University, Cleveland, Ohio; Plessey, Inc., Frenchtown, N.J.), W. A. Sanders, and J. L. Fiyalko Luttner (NASA, Lewis Research Center, Cleveland, Ohio). (*American Ceramic Society, Annual Meeting, 77th, Washington, D.C., May 7, 1975, Paper 97-B-75.*) *American Ceramic Society Bulletin*, vol. 56, Feb. 1977, p. 189-193. 17 refs. NASA-supported research.

Essentially pore-free Sialon bodies were obtained by pressure sintering for three blends (mol ratios of 4:1, 2:3, and 3:2) of  $\text{Si}_3\text{N}_4$  and  $\text{Al}_2\text{O}_3$  powders under the conditions of 27.6 MN/sq m and a temperature of 1700 C for 2 h. These dense bodies consist mainly of a Sialon solid solution with a minor amount of a particular second phase. The higher the  $\text{Al}_2\text{O}_3$  content (20 to 60 mol% range) in Sialon, the higher the densification rate. Fully dense bodies can be obtained at temperatures as low as 1500 C at 27.6 MN/sq m for 2 h with no second phase detectable by X-ray diffraction. A 100% dense body can be obtained by heating at 1700 C at 27.6 MN/sq m without a holding time.

B.J.

DATA SUMMARY: Relative densities of 100%  $\text{Si}_3\text{N}_4$ , 100%  $\text{Al}_2\text{O}_3$ , and Sialon powder compacts are examined as a function of transient temperature (in the range 0-2000 C) during the heating period of the pressure sintering run. Variables are elapsed time, chemical composition, measured immersion density, relative density, transient temperature, net change in relative density, holding temperature, and relative X-ray peak intensity. Five figures and one table include numeric data.

**A77-28351 \*** An oxide dispersion strengthened Ni-W-Al alloy with superior high temperature strength. T. K. Glasgow (NASA, Lewis Research Center, Cleveland, Ohio). In: *Superalloys: Metallurgy and manufacture, Proceedings of the Third International Symposium, Seven Springs, Pa., September 12-15, 1976.* (A77-28321 11-26) Baton Rouge, La., Claitor's Publishing Division, 1976, p. 385-394. 9 refs.

Oxide dispersion strengthened alloys based on the WAZ-20 nickel-base alloy were prepared by the mechanical alloying process described by Benjamin (1973), and evaluated. The results of microstructural examinations and mechanical property determinations are discussed. It is shown that WAZ-20, a high gamma-prime fraction alloy having a high gamma-prime solvus temperature, can be effectively dispersion strengthened. The strengths obtained were outstanding, especially at 1150 and 1205 C. The strength is attributed to a combination of highly alloyed matrix, elongated grain structure, and hard phase dispersion. Tensile ductility can be improved by post-recrystallization heat treatment. The new alloy shows some potential for low stress post-extrusion forming.

S.D.

**A77-32236 \*** Conductivity effects in high-voltage spacecraft insulating materials. R. C. Adamo, J. E. Nanevich (Stanford Research Institute, Menlo Park, Calif.), and N. Grier (NASA, Lewis Research Center, Cleveland, Ohio). *NASA and U.S. Air Force, Spacecraft Charging Technology Conference, Colorado Springs, Colo., Oct. 27-29, 1976, Paper. 24 p.* Contract No. NAS3-20080.

Laboratory measurements were performed to assess the influence of various external parameters on the conductivity properties of several typical and potential spacecraft insulating materials in a simulated space environment. The materials tested include Kapton, Teflon, quartz, and polyvinylidene fluoride. The parameters measured comprise sample thickness, temperature, applied voltage, illumination intensity and wavelength, and electron beam energy and current density. All tests were conducted in a vacuum chamber at a pressure of about one millionth Torr both with conventional optically-transparent gold front-surface electrodes and with the front surfaces of the test samples exposed directly to an electron beam. The data presented illustrate some of the complexities in electrical characteristics exhibited by the materials as a result of interactions with various conditions of their environment.

S.D.

**A77-40037 \*** Reactions of chromium with gaseous NaCl in an oxygen environment. C. A. Stearns, F. J. Kohl, and G. C. Fryburg (NASA, Lewis Research Center, Cleveland, Ohio). In: *Symposium on Properties of High Temperature Alloys with Emphasis on Environmental Effects, Las Vegas, Nev., October 17-22, 1976, Proceedings.* (A77-40012 18-26) Princeton, N.J., Electrochemical Society, Inc., 1976, p. 655-665. 19 refs.

Target collection techniques and high pressure mass spectrometric sampling have been used to study the formation of volatile chromium-containing species in the reaction of  $\text{Cr}_2\text{O}_3$  in the condensed state with gaseous  $\text{O}_2$  and NaCl. Experiments were performed at atmospheric pressure as a function of chromium temperature, oxygen pressure, and NaCl concentration. The major chromium-containing vapor species were found to be  $(\text{NaCl})_x\text{CrO}_3$ , with  $x = 1, 2$ , and 3, which are products of heterogeneous reactions on the surface. The kinetics indicate first order dependence on oxygen and sodium chloride pressures.

(Author)

**A77-47964 \*** Techniques for increasing boron fiber fracture strain. J. A. DiCarlo (NASA, Lewis Research Center, Cleveland, Ohio). *American Institute of Mining, Metallurgical and Petroleum Engineers, Annual Meeting, 106th, Atlanta, Ga., Mar. 6-10, 1977, Paper. 29 p.* 13 refs.

Improvement in the strain-to-failure of chemical-vapor deposition boron fibers is shown possible by contracting the tungsten boride core region and its inherent flaws. Results of three methods are presented in which etching and thermal-processing techniques were employed to achieve core flaw contraction. By internal stresses available in the boron sheath. After commercially and treatment-induced surface flaws were removed from 203-micron (8-mil) fibers, the core flaw was observed to be essentially the only source of fiber fracture. Thus, fiber strain-to-failure was found to improve by an amount equal to the treatment-induced contraction on the core flaw. To date, average fracture strains and stresses greater than 1.4% and 5.5 GN/sq m (800 ksi), respectively, have been achieved. Commercial feasibility considerations suggest as the most cost-effective technique that method in which as-produced fibers are given a rapid heat treatment above 700 C. Preliminary results concerning the contraction kinetics and fracture behavior observed with this technique are presented and discussed for both high-vacuum and argon-gas heat-treatment environments.

(Author)

**N77-13223\*** Ultrasonics, Inc., Irvine, Calif.  
**FLAME RETARDANT POLYPHOSPHAZENES Final Report.**  
 Jun. 1974 - Jul. 1976

K. L. Paciorek, D. W. Karle, and R. H. Kratzer Aug. 1976  
 101 p refs

(Contract NAS3-17829)

(NASA-CR-135090; SN-8262 F)

Avail: NTIS

HC A08/MF A01 CSCL 11G

Three processes for the preparation of polyphosphazenes were investigated: (1) the reaction of bisphosphines with diazides, (2) the condensation of bisdichlorophosphoranes with diamines; and (3) the treatment of bisphosphines with diamines in the presence of carbon tetrachloride followed by base dehydrohalogenation. All products obtained were of low molecular weight; the degree of polymerization did not exceed twelve repeating units. However, several compositions exhibited good thermal stability. No weight loss was observed up to 390 C when heated in air at 5 C/min. Treatment of bisphosphines with either an excess of a diazide or an excess of a diamine in the presence of carbon tetrachloride resulted in the production of difunctional phosphazenes which were respectively, azido and amino terminated. The reaction of these azido terminated extended monomers with bisphosphines did not produce high molecular weight materials. The bis-aminophosphazene prepared for the first time under this contract was successfully incorporated into a polyimide. Author

**N77-22256\*** Teledyne Microelectronics, Los Angeles, Calif.  
**A PARYLENE COATING PROCESS FOR HYBRID CIRCUITS**

1976 24 p refs

(Contract NAS3-19144)

(NASA-CR-135071) Avail: NTIS HC A02/MF A01 CSCL 11G

The parylene coating process developed during this program consists of (1) obtaining a hybrid cover with a hole in it, (2) sealing of the circuit with a hole in the cover, (3) parylene coating through the hole with the external leads protected from parylene by appropriate fixturing, and (4) sealing of the hole by soldering a pre-tinned kovar tab. Development of the above process required optimization of the parylene coater parameters to obtain a uniform consistent coating which could offer adequate protection to the circuits, fixture design for packages of various types, determination of the size of the deposition hole, and the amount of dimer charge per run, a process to hermetically seal the deposition holes and establishment of quality control techniques or acceptance criteria for the deposited film. Author

**N77-27231\*** United Technologies Research Center, East Hartford, Conn.

**GRAPHITE FIBER REINFORCED THERMOPLASTIC RESINS Final Report**

Richard C. Navak 18 Apr 1977 74 p refs

(Contract NAS3-20077)

(NASA-CR-135196; R77-912506-14)

Avail: NTIS

HC A04/MF A01 CSCL 11G

The results of a program designed to optimize the fabrication procedures for graphite thermoplastic composites are described. The properties of the composites as a function of temperature were measured and graphite thermoplastic fan exit guide vanes were fabricated and tested. Three thermoplastics were included in the investigation: polysulfone, polyethersulfone, and polyarylsulfone. Type HMS graphite was used as the reinforcement. Bending fatigue tests of HMS graphite/polyethersulfone demonstrated a gradual shear failure mode which resulted in a loss of stiffness in the specimens. Preliminary curves were generated to show the loss in stiffness as a function of stress and number of cycles. Fan exit guide vanes of HMS graphite polyethersulfone were satisfactorily fabricated in the final phase of the program. These were found to have stiffness and better fatigue behavior than graphite epoxy vanes which were formerly bill of material.

Author

## 28 PROPELLANTS AND FUELS

Includes rocket propellants, igniters, and oxidizers, storage and handling; and aircraft fuels.

For related information see also 07 Aircraft Propulsion and Power, 20 Spacecraft Propulsion and Power, and 44 Energy Production and Conversion.

**N77-15208\*** + National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio.

### BIBLIOGRAPHY ON LIQUEFIED NATURAL GAS (LNG) SAFETY

Paul M. Ordin Apr. 1976 654 p  
(NASA-TM-X-73408; E-8716) Avail: NTIS HC A99 CSCL 21D

Approximately 600 citations concerning safety of liquefied natural gas and liquid methane are presented. Each entry includes the title, author, abstract, source, description of figures, key references, and major descriptors for retrieving the document. An author index is provided as well as an index of descriptors.

Author

**N77-25345\*** National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio

### THERMAL STABILITY OF SOME AIRCRAFT TURBINE FUELS DERIVED FROM OIL SHALE AND COAL

Thaine W. Reynolds Washington Jun. 1977 33 p refs  
(NASA-TM-X-3551; E-9070) Avail: NTIS HC A03/MF A01 CSCL 21D

Thermal stability breakpoint temperatures are shown for 32 jet fuels prepared from oil shale and coal syncrudes by various degrees of hydrogenation. Low severity hydrotreated shale oils, with nitrogen contents of 0.1 to 0.24 weight percent, had breakpoint temperatures in the 477 to 505 K (400 to 450 F) range. Higher severity treatment, lowering nitrogen levels to 0.008 to 0.017 weight percent, resulted in breakpoint temperatures in the 505 to 533 K (450 to 500 F) range. Coal derived fuels showed generally increasing breakpoint temperatures with increasing weight percent hydrogen. Fuels below 13 weight percent hydrogen having breakpoints below 533 K (500 F). Comparisons are shown with similar literature data.

Author

### N77-10214\* General Dynamics/Convair, San Diego, Calif. CENTAUR PROPELLANT THERMAL CONDITIONING STUDY

M. H. Blatt, R. L. Pleasant, and R. C. Erickson Jul. 1976 131 p refs  
(Contract NAS3-19693)  
(NASA-CR-135032; CASD-NAS-76-026) Avail: NTIS HC A07/MF A01 CSCL 211

A wicking investigation revealed that passive thermal conditioning was feasible and provided considerable weight advantage over active systems using throttled vent fluid in a Centaur D-1s launch vehicle. Experimental wicking correlations were obtained using empirical revisions to the analytical flow model. Thermal subcoolers were evaluated parametrically as a function of tank pressure and NPSP. Results showed that the RL10 category 1 engine was the best candidate for boost pump replacement and the option showing the lowest weight penalty employed passively cooled acquisition devices, thermal subcoolers, dry ducts between burns and pumping of subcooler coolant back into the tank. A mixing correlation was identified for sizing the thermodynamic vent system mixer. Worst case mixing requirements were determined by surveying Centaur D-1T, D-1S, IUS, and space tug vehicles. Vent system sizing was based upon worst case requirements. Thermodynamic vent system/mixer weights were determined for each vehicle.

Author

**N77-12230\*** Atlantic Richfield Co., Harvey, Ill. Technical Center.

### SYNTHESIS AND ANALYSIS OF JET FUEL FROM SHALE OIL AND COAL SYNCRUCES

J. P. Gallagher, T. A. Collins, T. J. Nelson, M. J. Pedersen, M. G. Robison, and L. J. Wisinski 17 Nov. 1976 64 p refs  
(Contract NAS3-19747)  
(NASA-CR-135112; M1 76-1) Avail: NTIS HC A04/MF A01 CSCL 21D

Thirty-two jet fuel samples of varying properties were produced from shale oil and coal syncrudes, and analyzed to assess their suitability for use. TOSCO II shale oil and H-COAL and COED syncrudes were used as starting materials. The processes used were among those commonly in use in petroleum processing-distillation, hydrogenation and catalytic hydrocracking. The processing conditions required to meet two levels of specifications regarding aromatic, hydrogen, sulfur and nitrogen contents at two yield levels were determined and found to be more demanding than normally required in petroleum processing. Analysis of the samples produced indicated that if the more stringent specifications of 13.5% hydrogen (min.) and 0.02% nitrogen (max.) were met, products similar in properties to conventional jet fuels were obtained. In general, shale oil was easier to process (catalyst deactivation was seen when processing coal syncrudes), consumed less hydrogen and yielded superior products. Based on these considerations, shale oil appears to be preferred to coal as a petroleum substitute for jet fuel production.

Author

**N77-21248\*** Lockheed Missiles and Space Co., Sunnyvale, Calif.

### VAPOR INGESTION IN A CYLINDRICAL TANK WITH A CONCAVE ELLIPTICAL BOTTOM

Andrew Klavins 26 Feb. 1974 19 p refs  
(Contract NAS3-17798)  
(NASA-CR-135007; LMSC-D386845) Avail: NTIS HC A02/MF A01 CSCL 211

An approximate analytical technique is presented for estimating the liquid residual in a tank of arbitrary geometry due to vapor ingestion at any drain rate and acceleration level. The bulk liquid depth at incipient pull-through is defined in terms of the Weber and Bond numbers and two functions that describe the fluid velocity field and free surface shape appropriate to the tank geometry. Numerical results are obtained for the Centaur LH2 tank using limiting approximations to these functions.

Author

### N77-27241\* Boeing Commercial Airplane Co., Seattle, Wash. PRELIMINARY ANALYSIS OF AIRCRAFT FUEL SYSTEMS FOR USE WITH BROADENED SPECIFICATION JET FUELS Final Report

A. J. Pasion and I. Thomas Jun. 1977 82 p refs  
(Contract NAS3-19783)  
(NASA-CR-135198; D6-44538) Avail: NTIS HC A05/MF A01 CSCL 21D

An analytical study was conducted on the use of broadened specification hydrocarbon fuels in present day aircraft. A short range Boeing 727 mission and three long range Boeing 747 missions were used as basis of calculation for one-day-per-year extreme values of fuel loading, airport ambient and altitude ambient temperatures with various seasonal and climatic conditions. Four hypothetical fuels were selected: two high-vapor-pressure fuels with 35 kPa and 70 kPa RVP and two high-freezing-point fuels with -29 C and -18 C freezing points. In-flight fuel temperatures were predicted by Boeing's aircraft fuel tank thermal analyzer computer program. Boil-off rates were calculated for the high vapor pressure fuels and heating/insulation requirements for the high freezing point fuels were established. Possible minor and major heating system modifications were investigated with respect to heat output, performance and economic penalties for the high freezing point fuels.

Author

**N77-30271\*** National Bureau of Standards, Washington, D.C.

**FIRE RESEARCH SPECIALISTS: A DIRECTORY**

Nora H. Jason Jul. 1977 137 p

(NASA Order C-97823-B)

(NASA-CR-135089; NBSIR-77-1264)

Avail: NTIS

HC A07/MF A01 CSCL 13L

Specialists are listed from the United States and Canada who have made recent contributions to the fire literature, to the teaching of fire science or related subjects, or who have participated in or supported fire research programs. This work is an update of the 'Directory of Workers in the Fire Field'. The Directory is divided into three parts. The first part, the Specialists Index, is arranged alphabetically. The first line notes the name followed by the area(s) of specialization represented by Arabic numerals. These Arabic numerals are used throughout the Directory and are defined in a separate listing on page vii. The second and subsequent lines give the specialist's affiliation, mailing address, and telephone number. The second part, the Subject Specialty Index, alphabetically lists the subject areas and the corresponding specialist names. Entries are limited to two areas of specialization per individual. The third part, The Affiliation Index, alphabetically lists the corporate sources, noting the specialists therein. If a specialist was affiliated with an organization, the term 'Consultant' was used to group these individuals in the Affiliations Index.

Author

## 31 ENGINEERING (GENERAL)

Includes vacuum technology; control engineering; display engineering; and cryogenics.

**N77-10311\*** National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio.

### INLET NOISE SUPPRESSOR DESIGN METHOD BASED UPON THE DISTRIBUTION OF ACOUSTIC POWER WITH MODE CUTOFF RATIO

**c71**  
Edward J. Rice *In its Advan in Eng. Sci.* Vol 3 1976 p 883-894 refs (For primary document see N77-10305 01-31)  
Avail: NTIS HC A20/MF A01 CSCL 20A

A liner design for noise suppressors with outer wall treatment such as in an engine inlet is presented which potentially circumvents the problems of resolution in modal measurement. The method is based on the fact that the modal optimum impedance and the maximum possible sound power attenuation at this optimum can be expressed as functions of cutoff ratio alone. Modes with similar cutoff ratios propagate similarly in the duct and in addition propagate similarly to the far field. Thus there is no need to determine the acoustic power carried by these modes individually, and they can be grouped together as one entity. With the optimum impedance and maximum attenuation specified as functions of cutoff ratio, the off-optimum liner performance can be estimated using an approximate attenuation equation. Author

**N77-10312\*** National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio.

### ORIFICE RESISTANCE FOR EJECTION INTO A GRAZING FLOW

**c34**  
Kenneth J. Baumeister *In its Advan in Eng. Sci.* Vol 3 1976 p 895-905 refs (For primary document see N77-10305 01-31)  
Avail: NTIS HC A20/MF A01 CSCL 20D

To explain the decrease in orifice resistance with the addition of grazing flow, the flow from an orifice was modeled by using an inviscid analysis which is valid when the orifice flow total pressure is nearly the same as the free stream grazing flow total pressure. For steady outflow from an orifice into a grazing flow, the orifice flow can enter the main grazing flow in an inviscid manner without generating large eddies to dissipate the kinetic energy of the jet. From the analysis, a simple closed-form solution was developed for the steady resistance for ejection from an orifice into a grazing-flow field. The calculated resistance compares favorably with data for a flow regime where the total pressure difference between the grazing flow and the orifice flow is small. Author

**N77-11213\*** National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio.

### DESIGN STUDY OF STEADY-STATE 30-TESLA LIQUID-NEON-COOLED MAGNET

George M. Prok and Gerald V. Brown. Washington. Nov. 1976. 38 p. refs.  
(NASA-TN-D-8337, E-8780) Avail: NTIS HC A03/MF A01 CSCL 20L

A design for a 30-tesla, liquid-neon-cooled magnet was reported which is capable of continuous operation. Cooled by nonboiling, forced-convection heat transfer to liquid neon flowing at 2.8 cu m/min in a closed, pressurized heat-transfer loop and structurally supported by a tapered structural ribbon, the tape-wound coils with a high-purity-aluminum conductor will produce over 30 teslas for 1 minute at 850 kilowatts. The magnet will have an inside diameter of 7.5 centimeters and an outside diameter of 54 centimeters. The minimum current density at design field will be 15.7 kA/sq cm. Author

**N77-12236\*** National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio.

### SPUTTERING

T. Spalvins. 1976. 13 p. refs. Presented at the 25th Symp. of the Mech. Failures Prevent. Group, Gaithersburg, Md., 3-5 Nov. 1976; sponsored by NBS.  
(NASA-TM-X-73527, E-8944) Avail: NTIS HC A02/MF A01 CSCL 13H

The potential of using the sputtering process as a deposition technique is reviewed; however, the manufacturing and sputter etching aspects are also discussed. The basic mechanism for dc and rf sputtering is described. Sputter deposition is presented in terms of the unique advantageous features it offers such as versatility, momentum transfer, stoichiometry, sputter etching, target geometry (coating and complex surfaces), precise controls, flexibility, ecology, and sputtering rates. Sputtered film characteristics, such as strong adherence and coherence and film morphology, are briefly evaluated in terms of varying the sputtering parameters. Also discussed are some of the specific industrial areas which are turning to sputter deposition techniques. Author

**N77-13237\*** National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio.

### OVERVIEW OF NASA/OAST EFFORTS RELATED TO MANUFACTURING TECHNOLOGY

Neal T. Saunders. 11 Nov. 1976. 10 p. Presented at the MTAG-76 DOD Tri-service Conf. on Manufacturing Technol., Arlington, Tex., 8-11 Nov. 1976.  
(NASA-TM-X-73538) Avail: NTIS HC A02/MF A01 CSCL 13H

An overview of some of NASA's current efforts related to manufacturing technology and some possible directions for the future are presented. The topics discussed are: computer-aided design, composite structures, and turbine engine components. Author

**N77-28330\*** National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio.

### BOILING INCIPIENCE AND CONVECTIVE BOILING OF NEON AND NITROGEN

S. S. Papell and R. C. Hendricks. Aug. 1977. 18 p. refs. Presented at the joint meeting of the Cryog. Eng. Conf. and the Intern. Cryog. Mater. Conf., Boulder, Colo., 2-5 Aug. 1977.  
(NASA-TM-X-73615, E-9099) Avail: NTIS HC A02/MF A01 CSCL 20L

Forced convection and subcooled boiling heat transfer data for liquid nitrogen and liquid neon were obtained in support of a design study for a 30 tesla cryomagnet cooled by forced convection of liquid neon. The cryogen data obtained over a range of system pressures, fluid flow rates, and applied heat fluxes were used to develop correlations for predicting boiling incipience and convective boiling heat transfer coefficients in uniformly heated flow channels. The accuracy of the correlating equations was then evaluated. A technique was also developed to calculate the position of boiling incipience in a uniformly heated flow channel. Comparisons made with the experimental data showed a prediction accuracy of + or - 15 percent. Author

**N77-28331\*** National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio.

### EFFECT OF ICE CONTAMINATION OF LIQUID-NITROGEN DROPS IN FILM BOILING

G. J. Schoessow (Florida Univ., Gainesville), C. E. Chmielewski (Indiana Public Service Co., Plainfield), and K. J. Baumeister. Aug. 1977. 12 p. refs. Presented at 1977 Cryogenic Eng. Conf., Boulder, Colo., 2-5 Aug. 1977; sponsored by NBS.  
(NASA-TM-73704, E-9243) Avail: NTIS HC A02/MF A01 CSCL 20L

Previously reported vaporization time data of liquid nitrogen drops in film boiling on a flat plate are about 30 percent shorter than predicted from standard laminar film boiling theory. This theory, however, had been found to successfully correlate the data for conventional fluids such as water, ethanol, benzene, or carbon tetrachloride. Experimental evidence that some of the

discrepancy for cryogenic fluids results from ice contamination due to condensation is presented. The data indicate a fairly linear decrease in droplet evaporation time with the diameter of the ice crystal residue. After correcting the raw data for ice contamination along with convection, a comparison of theory with experiment shows good agreement. Author

**N77-30277\*** National Aeronautics and Space Administration, Lewis Research Center, Cleveland, Ohio.

**RECENT DEVELOPMENTS IN PHOTOVOLTAIC ENERGY BY ERDA/NASA-LERC** c44

James N. Deyo. In its Proc. of the ASPE/MSFC Symp. on Eng. and Productivity Gains from Space Technol. May 1977 p 69-85 (For primary document see N77-30273 21-31)

Avail: NTIS HC A13/MF A01 CSCL 10A

Application development activities were designed to stimulate the market for photovoltaics so that as costs are reduced there will be an increasing market demand to encourage the expansion of industrial solar array production capacity. Supporting these application development activities are tasks concerned with: (1) establishing standards and methodology for terrestrial solar cell calibration; (2) conducting standard and diagnostic measurements on solar cells and modules; and (3) conducting real time and accelerated testing of solar cell modules and materials of construction under outdoor sunlight conditions. J.H.

**N77-30296\*** National Aeronautics and Space Administration, Lewis Research Center, Cleveland, Ohio.

**TRANSFER OF MOLYBDENUM DISULFIDE TO VARIOUS METALS**

Gilbert C. Barton (Weber State College, Ogden, Utah) and Stephen V. Pepper. Aug. 1977 17 p refs

(NASA-TP-1019; E-8965) Avail: NTIS HC A02/MF A01 CSCL 07D

Sliding friction experiments were conducted with molybdenum disulfide single crystals in contact with sputter cleaned surfaces of copper, nickel, gold, and 304 stainless steel. Transfer of the molybdenum disulfide to the metals was monitored with Auger electron spectroscopy. Results of the investigation indicate molybdenum disulfide transfers to all clean metal surfaces after a single pass over the metal surface with film thickness observed to increase with repeated passes over the same surfaces. Large particle transfer occurs when the orientation of the crystallites is other than basal. This is frequently accompanied by abrasion of the metal. Adhesion of molybdenum disulfide films occurred readily to copper and nickel, less readily to 304 stainless steel, and even less effectively to the gold, which indicates a chemical effect. Author

**A77-26395 \*** Overview of NASA/OAST efforts related to manufacturing technology. N. T. Saunders (NASA, Lewis Research Center, Cleveland, Ohio). *Manufacturing Technology Advisory Group and U.S. Department of Defense, Tri-service Conference on Manufacturing Technology, Arlington, Tex., Nov. 8-11, 1976, Paper 9 p.*

Activities of the Office of Aeronautics and Space Technology (OAST) in a number of areas related to manufacturing technology are considered. In the computer-aided design area improved approaches are developed for the design of specific classes of components or structural subsystems. A generalized approach for the design of a complete aerospace vehicle is also developed. Efforts directed toward an increased use of composite materials in aerospace structures are also discussed and attention is given to projects concerned with the manufacture of turbine engine components. G.R.



## 32 COMMUNICATIONS

Includes land and global communications; communications theory; and optical communications.

For related information see also 04 Aircraft Communications and Navigation and 17 Spacecraft Communications, Command and Tracking.

**N77-11268\*** National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio.

### TEST PROGRAM FOR TRANSMITTER EXPERIMENT PACKAGE AND HEAT PIPE SYSTEM FOR THE COMMUNICATIONS TECHNOLOGY SATELLITE

James F. DePauw, Karl E. Reader, and John V. Staskus  
Washington Nov. 1976 38 p refs  
(NASA-TM-X-3455; E-8832) Avail: NTIS HC A03/MF A01 CSCL 17B

The test program is described for the 200 watt transmitter experiment package and the variable conductance heat pipe system which are components of the high-power transponder aboard the Communications Technology Satellite. The program includes qualification tests to demonstrate design adequacy, acceptance tests to expose latent defects in flight hardware, and development tests to integrate the components into the transponder system and to demonstrate compatibility. Author

**N77-21282\*** National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio.

### COMMUNICATIONS TECHNOLOGY SATELLITE OUTPUT-TUBE DESIGN AND DEVELOPMENT

Denis J. Connolly, Ralph Forman, C. L. Jones (Litton Industries, San Carlos, Calif.), Henry G. Kosmahl, and G. Richard Sharp  
Washington Apr. 1977 21 p refs  
(NASA-TM-X-3480; E-8776) Avail: NTIS HC A02/MF A01 CSCL 17B

The design and development of a 200-watt-output, traveling-wave tube (TWT) for the Communications Technology Satellite (CTS) is discussed, with emphasis on the design evolution during the manufacturing phase of the development program. Possible further improvements to the tube design are identified. Author

**N77-22310\*** National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio.

### A REAL TIME, LOW COST, DATA ACQUISITION TELECOMMUNICATION NETWORK

R. R. Schulte [1976] 22 p  
(NASA-TM-X-73645; E-9151) Avail: NTIS HC A02/MF A01 CSCL 17B

The real time, low cost data acquisition communication network described features the use of asynchronous ASCII code transmissions operating at 30 characters per second on the dial-up telephone system. The network features an elaborate, but easily generated error checking system, operating in a line-by-line demand-response mode. The system is readily adaptable for any low speed computer-to-computer data transmissions requiring high reliability in data transmission. The network was developed for the acquisition of prelaunch wind data from the Eastern Test Range at Cape Kennedy. Author

**N77-25372\*** National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio.

### COMPUTER PROGRAM FOR ANALYSIS OF COUPLED-CAVITY TRAVELING WAVE TUBES

Denis J. Connolly and Thomas A. Omalley Washington May 1977 53 p refs  
(NASA-TN-D-8492; E-8839) Avail: NTIS HC A04/MF A01 CSCL 09C

A flexible, accurate, large signal computer program was developed for the design of coupled cavity traveling wave tubes. The program is written in FORTRAN IV for an IBM 360/87 time sharing system. The beam is described by a disk model

and the slow wave structure by a sequence of cavities, or cells. The computational approach is arranged so that each cavity may have geometrical or electrical parameters different from those of its neighbors. This allows the program user to simulate a tube of almost arbitrary complexity. Input and output couplers, severs, complicated velocity tapers, and other features peculiar to one or a few cavities may be modeled by a correct choice of input data. The beam-wave interaction is handled by an approach in which the radio frequency fields are expanded in solutions to the transverse magnetic wave equation. All significant space harmonics are retained. The program was used to perform a design study of the traveling-wave tube developed for the Communications Technology Satellite. Good agreement was obtained between the predictions of the program and the measured performance of the flight tube. Author

**N77-29353\*** National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio.

### USERS' MANUAL FOR COMPUTER PROGRAM FOR ONE-DIMENSIONAL ANALYSIS OF COUPLED-CAVITY TRAVELING WAVE TUBES

Thomas A. Omalley and Denis J. Connolly Washington Aug. 1977 67 p refs  
(NASA-TM-X-3565; E-8900) Avail: NTIS HC A04/MF A01 CSCL 09C

The use of the coupled cavity traveling wave tube for space communications has led to an increased interest in improving the efficiency of the basic interaction process in these devices through velocity resynchronization and other methods. To analyze these methods, a flexible, large signal computer program for use on the IBM 360/67 time-sharing system has been developed. The present report is a users' manual for this program. Author

**N77-31355\*** National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio.

### ASDAR (AIRCRAFT TO SATELLITE DATA RELAY) FLIGHT TEST REPORT

Edward J. Domino, Robert R. Lovell, Martin J. Conroy, and David H. Culp Aug. 1977 21 p  
(NASA-TM-73744; E-9311) Avail: NTIS HC A02/MF A01 CSCL 17B

The aircraft to Satellite Data Relay (ASDAR), an airborne data collection system that gathers meteorological data from existing aircraft instrumentation and relays it to ground user via a geo-synchronous meteorological satellite, is described and the results of the first test flight on a commercial Boeing 747 aircraft are presented. The flight test was successful and verified system performance in the anticipated environment. Author

**A77-24327 \*** United States societal experiments via the Communications Technology Satellite. P. L. Donoughe (NASA, Lewis Research Center, Cleveland, Ohio). In: International Conference on Communications, 12th, Philadelphia, Pa., June 14-16, 1976, Conference Record, Volume 1. (A77-24326 09-32) New York, Institute of Electrical and Electronics Engineers, Inc., 1976, p. 1-17 to 22.

After a brief description of the Communication Technology Satellite and its U.S. coverage, the U.S. societal experiments via the CTS are discussed. These include education (college curriculum sharing, and project interchange), health care (biomedical communications, health communications, and communication support for decentralized education), and community and special experiments (satellite library information network, and transportable earth terminal). B.J.

c-2

**A77-28301\*** The Communications Technology Satellite (CTS) Program. W. M. Evans, N. G. Davies (Department of Communications, Communications Research Centre, Ottawa, Canada), and W. H. Hawersaat (NASA, Lewis Research Center, Cleveland, Ohio). In: Communication satellite systems: An overview of the technology. (A77-28301 11-32) New York, IEEE Press, 1976, p. 13-18.

The purposes of the joint Canadian-U.S. Communications Technology Satellite (CTS) Program are (1) to conduct satellite communication systems experiments using the 12- and 14-GHz bands and low-cost transportable ground terminals, (2) to develop and flight test a power amplifier tube having a greater than 50% efficiency with a saturated power output of 200 W at 12 GHz, (3) to develop and flight test a lightweight extendible solar array with an initial power output greater than 1 kW, and (4) to develop and flight test a 3-axis stabilization system to maintain accurate antenna boresight positioning on a spacecraft with flexible appendages. Brief descriptions of these experiments and of the ground facilities are provided.

P.T.H.

**N77-24332\*** TRW Defense and Space Systems Group, Redondo Beach, Calif.

**TRANSMITTER EXPERIMENT PACKAGE FOR THE COMMUNICATIONS TECHNOLOGY SATELLITE**

B. Farber, D. S. Goldin, B. Marcus, and P. Mock [1977] 200 p refs

(Contract NAS3-15839)

(NASA-CR-125035) Avail: NTIS HC A09/MF A01 CSCL 17B

The operating requirements, system design characteristics, high voltage packaging considerations, nonstandard components development, and test results for the transmitter experiment package (TEP) are described. The TEP is used for broadcasting power transmission from the Communications Technology Satellite. The TEP consists of a 12 GHz, 200-watt output stage tube (OST), a high voltage processing system that converts the unregulated spacecraft solar array power to the regulated voltages required for OST operation, and a variable conductance heat pipe system that is used to cool the OST body.

Author

### 33 ELECTRONICS AND ELECTRICAL ENGINEERING

Includes test equipment and maintainability; components, e.g., tunnel diodes and transistors; microminiaturization; and integrated circuitry.

For related information see also 60 Computer Operations and Hardware and 76 Solid-State Physics.

**N77-10435\*** National Aeronautics and Space Administration, Lewis Research Center, Cleveland, Ohio.

**EXPERIMENTAL PERFORMANCE OF A SMALL SIZE TWO STAGE DEPRESSED COLLECTOR FOR A 4.8-9.6 GHz HIGH PERFORMANCE TWT** Interim Report, Apr. 1975 - Jun. 1976

P. Ramins and T. Fox Sep. 1976 25 p refs Prepared in cooperation with Aeronaut. Systems Div., Wright-Patterson AFB Ohio

(NASA-TM-X-73513; E-8920) Avail. NTIS HC A02/MF A01 CSCL 09A

Three simple small size two stage depressed collectors were designed and experimentally evaluated in conjunction with a 330 to 520 watt CW, 4.8 to 9.6 GHz traveling wave tube (TWT). Each of the three designs produced a minimum collector efficiency of 80.0 percent considering saturated TWT operation at the maximum of output frequency and at band edges. The highest minimum collector efficiency produced was 80.5 percent with a two stage depressed collector of 4.8 cm diameter by 7 cm high internal dimensions.

Author

**N77-11295\*** National Aeronautics and Space Administration, Lewis Research Center, Cleveland, Ohio.

**DESCRIPTION AND EXPECTED PERFORMANCE OF FLIGHT-MODEL, 12-GIGAHERTZ, OUTPUT STAGE TUBE FOR THE COMMUNICATIONS TECHNOLOGY SATELLITE** Gerald J. Chomos and Arthur N. Curren Washington Oct. 1976 22 p refs

(NASA-TM-X-3441; E-8777) Avail. NTIS HC A02/MF A01 CSCL 09A

The flight model output stage tube for the Communications Technology Satellite is described. The output stage tube is a 12-GHz, 200-W, coupled cavity traveling wave tube. The tube has a multistage depressed collector for efficiency enhancement. Collector cooling is accomplished by direct radiation to space. Expected rf performance and factors affecting on orbit performance and life are discussed.

Author

**N77-12297\*** National Aeronautics and Space Administration, Lewis Research Center, Cleveland, Ohio.

**AN 82 TO 84 PERCENT EFFICIENT, SMALL SIZE, 2 AND 4 STAGE DEPRESSED COLLECTOR FOR OCTAVE BAND-WIDTH HIGH PERFORMANCE TWT'S**

H. Kosmahl and P. Ramins 1976 9 p Presented at the Intern. Electron Devices Meeting, Washington, D. C., 6-8 Dec. 1976

(NASA-TM-X-73572; E-9021) Avail. NTIS HC A02/MF A01 CSCL 09A

Improvements were carried out on a TWT (traveling wave tube) for use in EMC (electronic countermeasure) systems by applying MDC (multi-stage depressed collector) and spent-beam refocusing techniques. The MDC geometric design consists of six collecting elements (electrodes) at ground and cathode potentials operating in 2 or 4 stage configuration. The refocusing system designed allows a controlled beam expansion to the point that space charge becomes negligible at the MDC entrance. Simultaneously, the standard deviation of the radial velocity (angular spread) is reduced. This system provides an analog real time readout of P(recovered). Data on all tests is obtained with an automated data acquisition system.

I.M.

**N77-13331\*** National Aeronautics and Space Administration, Lewis Research Center, Cleveland, Ohio.

**MICROWAVE POWER TUBES FOR SPACE APPLICATIONS**

Henry Kosmahl 1976 8 p Presented at Intern. Electron Devices Meeting, Washington, D. C., 6-8 Dec. 1976

(NASA-TM-X-73571; E-9020) Avail. NTIS HC A02/MF A01 CSCL 09A

Feasibility evaluations of klystron amplifiers for conversion of solar power in synchronous orbit into microwave power at 2.4 GHz and transmission to earth were carried out. It was found that amplifiers and klystrons, using a depressed collector augmentation, can achieve efficiencies in excess of 80% if the power output is kept higher than 50 kW. Body wound selenoid provides the needed beam-focusing field. Narrow bandwidth requirements permit a low cathode loading density of 0.5 A/sq cm produced at approximately 850 centigrades. Emission tests indicate a potential life expectancy of 20 to 40 years.

I.M.

**N77-17357\*** National Aeronautics and Space Administration, Lewis Research Center, Cleveland, Ohio.

**METHOD OF ELECTRICALLY PRE-STRESSING INSULATION TO PROVIDE DIRECTIONAL INCREASE IN dc POTENTIAL BREAKDOWN** Patent Application

Irving G. Hansen, inventor (to NASA) Filed 31 Jan. 1977 7 p

(NASA-Case-LEW-12273-1; US-Patent-Appl-SN-764253) Avail. NTIS HC A02/MF A01 CSCL 09C

A method was provided for electrically pre-stressing an insulator to increase the dc breakdown strength of the insulator in a given direction. The method comprises placing an uncured, durable insulating material, such as an epoxy resin, in an electric field and curing the insulating material while maintaining the field so as to capture an electric field within the insulating material. The electric field biases the breakdown potential in a given direction so that the insulation is able to withstand a substantially greater dc operating voltage of the appropriate polarity. NASA

**N77-17380\*** National Aeronautics and Space Administration, Lewis Research Center, Cleveland, Ohio.

**TRAVELING WAVE TUBE CIRCUIT** Patent Application

Denis J. Connolly, inventor (to NASA) Filed 15 Feb. 1977 12 p

(NASA-Case-LEW-12013-1; US-Patent-Appl-SN-768795) Avail. NTIS HC A02/MF A01 CSCL 09C

The traveling wave tube (TWT) has a slow wave structure (SWS) which is severed into two or more sections. A signal path connects the end of an SWS section to the beginning of the following SWS section. The signal path comprises an impedance matching coupler (IMC), followed by an isolator, a phase correcting filter, a variable phase shifter, and a second IMC. The aggregate band pass characteristic of the components in the signal path is chosen to reject, or strongly attenuate, all frequencies outside the desired operating frequency range of the TWT and yet pass with minimal attenuation in the forward direction, all frequencies within the desired operating frequency range.

NASA

**N77-22388\*** National Aeronautics and Space Administration, Lewis Research Center, Cleveland, Ohio.

**ELECTRIC VEHICLE POWER TRAIN INSTRUMENTATION: SOME CONSTRAINTS AND CONSIDERATIONS**

James E. Triner and Irving G. Hansen 1977 21 p refs Presented at Intern. Elec. Vehicle Exposition, Chicago, 26-29 Apr. 1977; sponsored by Elec. Vehicle Council

(Contract EC-77-A-31-1011)

(NASA-TM-X-73629; E-9125; ERDA/NASA-1011/77/1) Avail. NTIS HC A02/MF A01 CSCL 09A

The application of pulse modulation control (choppers) to dc motors creates unique instrumentation problems. In particular, the high harmonic components contained in the current waveforms

require frequency response accommodations not normally considered in dc instrumentation. In addition to current sensing, accurate power measurement requires not only adequate frequency response but must also address phase errors caused by the finite bandwidths and component characteristics involved. The implications of these problems are assessed. Author

**N77-22391\*** National Aeronautics and Space Administration, Lewis Research Center, Cleveland, Ohio.

**DEVELOPMENT AND PERFORMANCE OF POWER PROCESSOR SYSTEM FOR 2-GIGAHERTZ, 200-WATT AMPLIFIER FOR COMMUNICATIONS TECHNOLOGY SATELLITE**

Clifford E. Siegert, Francis Gourash, and Richard W. Vasicek  
Washington May 1977 41 p refs  
(NASA-TM-X-3516, E-8893) Avail: NTIS HC A03/MF A01 CSCL 09A

The electrical and environmental requirements for a power processor system (PPS) designed to supply the appropriate voltages and currents to a 200-watt traveling wave tube (TWT) for a communication technology satellite is described. A block diagram of the PPS, the interface requirements between the PPS and spacecraft, the interface requirements between the PPS and 200-watt TWT, and the environmental requirements of the PPS are presented. Also included are discussions of protection circuits, interlocking sequences, and transient requirements. Predictions of the flight performance, based on ground test data, are provided. Author

**N77-24385\*** National Aeronautics and Space Administration, Lewis Research Center, Cleveland, Ohio.

**A REGULATED HIGH EFFICIENCY, LIGHTWEIGHT CAPACITOR-DIODE MULTIPLIER DC TO DC CONVERTER Patent Application**

W. T. Harrigill and Ira T. Myers, inventors (to NASA) Filed 27 May 1977 12 p  
(NASA-Case-LEW-12791-1; US-Patent-Appl-SN-801432) Avail: NTIS HC A02/MF A01 CSCL 09A

A voltage multiplier is described which has a capacitor-diode voltage multiplying network which is fed with voltage pulses from a dc source through a first switching means. Pulses of a second polarity are also supplied through a second switching means to the input of the capacitor-diode voltage multiplier from a second dc source whose voltage is adjustable to change the voltage of the pulses of second polarity. The switching means are alternately rendered conducting by signals from a control circuit. The second dc source may be controlled by a voltage comparator which compares the output voltage of the capacitor-diode voltage multiplier to the reference source. NASA

**N77-26385\*** National Aeronautics and Space Administration, Lewis Research Center, Cleveland, Ohio.

**PROCESS FOR PREPARING LIQUID METAL ELECTRICAL CONTACT DEVICE Patent**

Robert R. Lovell, Frank D. Berkopec, and David H. Culp, inventors (to NASA) Issued 17 May 1977 4 p Filed 24 Jul. 1976 Supersedes N76-29480 (14 - 20, p 2591)  
(NASA-Case-LEW-11978-1; US-Patent-4,023,266; US-Patent-Appl-SN-708658; US-Patent-Class-29-628; US-Patent-Class-29-627; US-Patent-Class-29-622; US-Patent-Class-29-630E; US-Patent-Class-204-32A) Avail: US Patent Office CSCL 09A

The parts of an electrical contact device are treated by sputter etching to remove the parent metal oxide. Prior to exposure of the electrodes to any oxygen, a sacrificial metal is sputter deposited on the parts. Preferably this sacrificial metal is one that oxidizes slowly and is readily dissolved by the liquid metal. The sacrificial metal may then be removed from unwanted areas. The remainder of the ring and the probe to be wet by the liquid metal are submerged in the liquid metal or the liquid metal is flushed over these areas, preferably while they are being slightly abraded, until all the sacrificial material on these portions is wet by the liquid metal. In doing so the liquid metal dissolves the sacrificial

metal and permanently wets the parent metal. Preferred materials used in the process and for the electrodes of electrical contact devices are high purity (99.0%) nickel or AISI type 304 stainless steel for the electrical contact devices, gallium as the liquid metal, and gold as the sacrificial material.

Official Gazette of the U.S. Patent Office

**N77-27306\*** National Aeronautics and Space Administration, Lewis Research Center, Cleveland, Ohio.

**THE SOLID STATE REMOTE POWER CONTROLLER: ITS STATUS, USE AND PERSPECTIVE**

G. R. Sundberg and W. W. Billings (Westinghouse Electric Corp., Lima, Ohio) 1977 13 p refs Presented at 1977 Power Elec Specialists Conf., Palo Alto, Calif., 14-16 Jun. 1977, sponsored by IEEE  
(NASA-TM-73695; E-9231) Avail: NTIS HC A02/MF A01 CSCL 09C

Solid state remote power controllers (RPC's) are now available to control and protect all types of loads in both ac and dc power distribution systems. RPC's possess many outstanding qualities that make them attractive for most system applications. A review is given of the present state-of-the-art and applications for solid state RPC's for both aerospace and terrestrial systems. Author

**N77-28385\*** National Aeronautics and Space Administration, Lewis Research Center, Cleveland, Ohio.

**SUSTAINED ARC IGNITION SYSTEM Patent**

Arthur G. Birchenough, inventor (to NASA) Issued 5 Jul. 1977 10 p Filed 3 Jun. 1976 Supersedes N75-25056 (13 - 16, p 1956)

(NASA-Case-LEW-12444-1; US-Patent-4,033,316; US-Patent-Appl-SN-583485; US-Patent-Class-123-148E; US-Patent-Class-123-148CB; US-Patent-Class-315-176) Avail: US Patent Office CSCL 09C

Circuitry for maintaining an arc or spark across a spark gap for a desired length of time is disclosed. A high voltage, direct current source is connected in series with a secondary winding of a high voltage, stepup transformer or coil and a spark gap such as a spark plug for example. The high voltage source may be on continuously or may be turned on and off by a control circuit such as a solid state switch which is, in turn, responsive to a timing device such as a set of ignition contact points or a magnetic pulse generator operating in synchronism with a spark ignition engine. The timing device also provides signals to a current switching circuit which interrupts current flow through a primary winding of the high voltage coil at the prescribed time that a spark is desired at the spark gap.

Official Gazette of the U.S. Patent Office

**N77-28393\*** National Aeronautics and Space Administration, Lewis Research Center, Cleveland, Ohio.

**DESIGN AND PROTOTYPE FABRICATION OF A 30 TESLA CRYOGENIC MAGNET**

G. M. Prok, M. C. Swanson, and G. V. Brown Aug. 1977 16 p refs Presented at the 1977 Cryog Eng Conf., Boulder, Colo., 2-5 Aug. 1977  
(NASA-TM-X-73660; E-9177) Avail: NTIS HC A02/MF A01 CSCL 20C

A liquid neon cooled magnet was designed to produce 30 teslas in steady operation. To ensure the correctness of the heat transfer relationships used, supercritical neon heat transfer tests were made. Other tests made before the final design included tests on the effect of the magnetic field on pump motors, tensile shear tests on the cryogenic adhesives, and simulated flow studies for the coolant. The magnet will consist of two pairs of coils, cooled by forced convection of supercritical neon. Heat from the supercritical neon will be rejected through heat exchangers which are made of roll bonded copper panels and are submerged in a pool of saturated liquid neon. A partial mock up coil was wound to identify the tooling required to wind the magnet. This was followed by winding a prototype pair of coils. The prototype winding established procedures for fabricating the final magnet and revealed slight changes needed in the final design. Author

**N77-29402\*** National Aeronautics and Space Administration, Lewis Research Center, Cleveland, Ohio.

**SUMMARY OF THE CTS TRANSIENT EVENT COUNTER DATA AFTER ONE YEAR OF OPERATION**

N. John Stevens, Vernon W. Kline, and J. Victor Gore (Communications Research Center, Ottawa) Jul. 1977 28 p refs Presented at the Nucl. and Radiation Effects Conf., Williamsburg, Va., 12-15 1977; sponsored by the Inst. of Elec. and Electron. Engr.

(NASA-TM-73710; E-9249) Avail: NTIS HC A03/MF A01 CSCL 09C

The satellite electrical system Transient Event Counter (TEC) senses and counts transients in three separate satellite wiring harnesses. Recently, anomalous behavior of geosynchronous satellites has been attributed to the electrostatic charging of spacecraft surfaces by the environment during geomagnetic substorm activity, resulting in uncommanded switching of logic circuits. The function of the TEC is to count transients to identify the numbers and distributions of uncommanded pulses capable of switching typical spacecraft logic systems; a large number of transients have occurred without causing any anomalous electronic switching events in the satellite systems. The character of the transients seems to imply that additional sensors are required to understand the discharge phenomenon on large satellites. The results of this experiment indicate that satellite system immunity to discharge related electronic switching anomalies can be obtained by filtering out the harness transients. Author

**N77-30314\*** National Aeronautics and Space Administration, Lewis Research Center, Cleveland, Ohio.

**STATISTICS OF THE RADIATED FIELD OF A SPACE-TO-EARTH MICROWAVE POWER TRANSFER SYSTEM**

Grady H. Stevens and Gary Leininger (Toledo Univ., Ohio) [1976] 39 p refs

(NASA-TM-X-73684; E-9217) Avail: NTIS HC A02/MF A01 CSCL 20N

Statistics such as average power density pattern, variance of the power density pattern and variance of the beam pointing error are related to hardware parameters such as transmitter rms phase error and rms amplitude error. Also a limitation on spectral width of the phase reference for phase control was established. A 1 km diameter transmitter appears feasible provided the total rms insertion phase errors of the phase control modules does not exceed 10 deg, amplitude errors do not exceed 10% rms, and the phase reference spectral width does not exceed approximately 3 kHz. With these conditions the expected radiation pattern is virtually the same as the error free pattern, and the rms beam pointing error would be insignificant (approximately 10 meters). Author

**N77-32400\*** National Aeronautics and Space Administration, Lewis Research Center, Cleveland, Ohio.

**EFFICIENCY ENHANCEMENT OF OCTAVE-BANDWIDTH TWT'S BY THE USE OF MULTISTAGE DEPRESSED COLLECTORS Interim Report**

Peter Ramins and Thomas A. Fox Sep. 1977 28 p refs Sponsored by AFSC

(NASA-TM-73779; E-9335) Avail: NTIS HC A03/MF A01 CSCL 09C

A small size two and four stage depressed collector was evaluated in conjunction with a 4.8 to 9.6 GHz traveling wave tube of 325 to 675 W power output. In spite of large fixed traveling wave tube losses, very significant efficiency enhancement was demonstrated with both the two and four stage multistage depressed collectors (MDC). The improvement in the overall efficiency ranged from a factor of 2.5 to 3.0 for the two stage MDC and a factor of 3.0 to 3.5 for the four stage MDC. An overall efficiency of 37.0 to 44.3 percent across the frequency band was demonstrated with the use of harmonic injection. Author

**A77-20269\*** A contribution to computer analysis of coupled-cavity traveling wave tubes. D. J. Connolly and T. A. O'Malley (NASA, Lewis Research Center, Cleveland, Ohio). *IEEE Transactions on Electron Devices*, vol. ED-24, Jan. 1977, p. 27-31. 14 refs.

A flexible accurate large-signal computer program has been developed for the design of coupled-cavity traveling wave tubes. The program is written for a TSS-360 time sharing system. The beam is described by a disk model and the slow wave structure by a sequence of cavities or cells. The computational approach is arranged so that each cavity may have different geometrical or electrical parameters than its neighbors. This allows the program user to simulate a tube of almost arbitrary complexity. Input and output couplers, severs, complicated velocity tapers, and other features peculiar to one or a few cavities may be modeled by a correct choice of input data. The beam-wave interaction is handled by a new approach in which the RF fields are expanded in solutions to the TM wave equation retaining all significant space harmonics. The program was used to perform a design study of the TWT developed for the CTS satellite. Good agreement was obtained between the predictions of the program and the measured performance of the flight tube. The internal check on power balance was satisfied within plus or minus 0.2 per cent of input beam power. (Author)

**A77-20270\*** Analysis of spent beam refocusing to achieve optimum collector efficiency. N. Stankiewicz (NASA, Lewis Research Center, Cleveland, Ohio). *IEEE Transactions on Electron Devices*, vol. ED-24, Jan. 1977, p. 32-36. 8 refs.

A reasonable criterion for evaluating the effectiveness of spent beam refocusing is the reduction of spent beam turbulence. The rms deviation of particle angles where the angles are calculated from the ratio of radial velocity to axial velocity is one measure of beam turbulence. It is demonstrated that the angular deviation can be reduced by almost half in some magnetic field configurations. Experimental evidence indicates that beam processing of this type is most likely to yield an optimum collector efficiency. (Author)

**A77-20271\*** Small-size 81- to 83.5-percent efficient 2- and 4-stage depressed collectors for octave-bandwidth high-performance TWT's. H. G. Kosmahl and P. Ramins (NASA, Lewis Research Center, Cleveland, Ohio). *IEEE Transactions on Electron Devices*, vol. ED-24, Jan. 1977, p. 36-44. 11 refs.

In a joint USAF-NASA Program, Lewis Research Center is carrying out an efficiency improvement program on traveling wave tubes for use in electronic counter measures by applying multistage depressed collector (MDC) and spent beam refocusing techniques. In the analytic part of the effort, three-dimensional electron trajectories are computed throughout the TWT. On the experimental side, tube performance is evaluated first without the MDC; then, the spent beam is analyzed for symmetry, circularity, and velocity spread. The three-dimensional theory predicts a MDC-efficiency, at mid-band, of 81 per cent for a 2-stage MDC with symmetric, circular, and optimally refocused beams and 85.5 per cent for a 4-stage MDC. Experimental results to date have yielded MDC efficiencies of a minimum of 81 and 83 per cent for a 2- and 4-stage MDC, respectively, across a one-octave bandwidth of a 4.8 to 9.6 GHz 330-to-550-W TWT. (Author)

**A77-20274\*** Use of Auger spectroscopy in the evaluation of thermionic cathodes. R. Forman (NASA, Lewis Research Center, Cleveland, Ohio). *IEEE Transactions on Electron Devices*, vol. ED-24, Jan. 1977, p. 56-61. 17 refs.

Auger spectroscopy has been used to evaluate the properties of 'good' and 'poor' impregnated tungsten cathodes used in high-power microwave wave tubes. The results were interpreted to analyze failure modes in cathodes removed from TWT's because of poor emission characteristics. Most of the poor cathodes evaluated in this program were obtained from fabricated electron guns that had been

employed and discarded from the 200-W TWT tubes developed for the Communication Technology Satellite program. The results of these measurements have shown there are at least two types of failure modes that one observes with poor cathodes. They are (1) chemical contamination of the cathode surface and (2) low partial layer barium coverage of the cathode surface. (Author)

**A77-26398 \* #** An 82 to 84 percent efficient, small size, 2 and 4 stage depressed collector for octave bandwidth high performance TWT's. H. Kosmahl and P. Ramins (NASA, Lewis Research Center, Cleveland, Ohio). *Institute of Electrical and Electronics Engineers, International Electron Devices Meeting, Washington, D.C., Dec. 5-8, 1976, Paper.* 9 p.

**A77-32245 \* #** A production parylene coating process for hybrid microcircuits. V. S. Kale (Teledyne, Inc., Microelectronics Div., Los Angeles, Calif.) and T. J. Riley (NASA, Lewis Research Center, Cleveland, Ohio). *Institute of Electrical and Electronics Engineers, Electronic Components Conference, Arlington, Va., May 16-18, 1977, Paper.* 8 p. 5 refs. Contract No. NAS3-19144.

The real impetus for developing a production parylene coating process for internal hybrid passivation came as a result of the possibility of loose conductive particles in hybrid microelectronic circuits, causing intermittent and sometimes permanent failures. Because of the excellent mechanical properties of parylene, it is capable of securing the loose particles in place and prevent such failures. The process of coating described consists of (1) vaporizing the initial charge, which is in the form of a dimer; (2) conversion of the dimer into a reactive monomer; and (3) deposition and subsequent polymerization of the monomer in the deposition chamber which forms a uniform parylene film over all the cold surfaces in contact. Experimental results are discussed in terms of wire bond reliability, resistor drift, high-temperature storage characteristics of parylene, and coating acceptance standards. It is concluded that internal cavities of microelectronic circuits can be successfully coated with parylene provided appropriate tooling is used to protect external leads from the parylene monomer. S.D.

**A77-40953 \*** Formulation of a methodology for power circuit design optimization. Y. Y. M. Bachmann, F. C. Y. Lee (TRW Defense and Space Systems Group, Redondo Beach, Calif.), and J. E. Triner (NASA, Lewis Research Center, Cleveland, Ohio). *In: Power Electronics Specialists Conference, Cleveland, Ohio, June 8-10, 1976, Record.* (A77-40951 19-33) New York, Institute of Electrical and Electronics Engineers, Inc., 1976, p. 35-44. 16 refs. Contract No. NAS3-19690.

A methodology for optimizing power-processor designs is described which achieves optimization with respect to some power-processor characteristic deemed particularly desirable by the designer, such as weight or efficiency. Optimization theory based on Lagrange multipliers is reviewed together with nonlinear programming techniques employing penalty functions. The methodology, the task of which is to minimize an objective function subject to design constraints, is demonstrated with the aid of four examples: optimum-weight core selection for an inductor with a predetermined winding size, optimum-weight inductor design with a given loss constraint, optimum-loss inductor design with a given weight constraint, and a comparison of optimum-weight single- and two-stage input-filter designs with identical loss and other requirement constraints. Closed-form solutions for the first three examples are obtained by applying the Lagrange-multiplier method, but solutions for the last example are found numerically through the use of the sequential unconstrained minimization technique. F.G.M.

**A77-40955 \*** Modeling of switching regulator power stages with and without zero-inductor-current dwell time. F. C. Lee, Y. Yu (TRW Defense and Space Systems Group, Redondo Beach, Calif.), and J. E. Triner (NASA, Lewis Research Center, Cleveland, Ohio). *In: Power Electronics Specialists Conference, Cleveland, Ohio, June 8-10, 1976, Record.* (A77-40951 19-33) New York, Institute of Electrical and Electronics Engineers, Inc., 1976, p. 62-72. 10 refs. Contract No. NAS3-19690.

State space techniques are employed to derive accurate models for buck, boost, and buck/boost converter power stages operating with and without zero-inductor-current dwell time. A generalized procedure is developed which treats the continuous-inductor-current mode without the dwell time as a special case of the discontinuous-current mode, when the dwell time vanishes. An abrupt change of system behavior including a reduction of the system order when the dwell time appears is shown both analytically and experimentally. (Author)

**A77-40959 \*** Ultrasonic evaluation of high voltage circuit boards. S. J. Klima and T. J. Riley (NASA, Lewis Research Center, Cleveland, Ohio). *In: Power Electronics Specialists Conference, Cleveland, Ohio, June 8-10, 1976, Record.* (A77-40951 19-33) New York, Institute of Electrical and Electronics Engineers, Inc., 1976, p. 128-135. 7 refs.

Preliminary observations indicate that an ultrasonic scanning technique may be useful as a quick, low cost, nondestructive method for judging the quality of circuit board materials for high voltage applications. Corona inception voltage tests were conducted on fiberglass-epoxy and fiberglass-polyimide high pressure laminates from 20 to 140 C. The same materials were scanned ultrasonically by utilizing the single transducer, through-transmission technique with reflector plate, and recording variations in ultrasonic energy transmitted through the board thickness. A direct relationship was observed between ultrasonic transmission level and corona inception voltage. The ultrasonic technique was subsequently used to aid selection of high quality circuit boards for the Communications Technology Satellite. (Author)

**A77-40962 \*** Regulation of a lightweight high efficiency capacitor diode voltage multiplier dc-dc converter. W. T. Harrigill, Jr. and I. T. Myers (NASA, Lewis Research Center, Cleveland, Ohio). *In: Power Electronics Specialists Conference, Cleveland, Ohio, June 8-10, 1976, Record.* (A77-40951 19-33) New York, Institute of Electrical and Electronics Engineers, Inc., 1976, p. 186-189.

A method for the regulation of a capacitor diode voltage multiplier dc-dc converter has been developed which has only minor penalties in weight and efficiency. An auxiliary inductor is used, which only handles a fraction of the total power, to control the output voltage through a pulse width modulation method in a buck boost circuit. (Author)

**A77-50454 \*** Traveling-wave tube reliability estimates, life tests, and space flight experience. V. R. Lalli (NASA, Lewis Research Center, Cleveland, Ohio) and C. E. Speck (Case-Western-Reserve University, Cleveland, Ohio). *In: Annual Reliability and Maintainability Symposium, Philadelphia, Pa., January 18-20, 1977, Proceedings.* (A77-50451 24-38) Piscataway, N.J., Institute of Electrical and Electronics Engineers, Inc., 1977, p. 12-20. 14 refs.

Methods of estimating the reliability of TWT's are reviewed. Values for the mean time between failure of medium-power and high-power tubes were computed from data in the literature. P.T.H.

**N77-18248\* #** Colorado State Univ., Fort Collins. Dept. of Physics.  
**INDUSTRIAL ION SOURCE TECHNOLOGY Annual Report**  
Harold R. Kaufman Nov. 1976 99 p refs  
(Grant NSG-3086)  
(NASA-CR-135149) Avail: NTIS HC A05/MF A01 CSCL

09C

A 30 cm electron bombardment ion source was designed and fabricated for micromachining and sputtering applications. This source has a multipole magnetic field that employs permanent magnets between permeable pole pieces. An average ion current density of 1 ma/sq cm with 500 eV argon ions was selected as a design operating condition. The ion beam at this operating condition was uniform and well collimated, with an average variation of plus or minus 5 percent over the center 20 cm of the beam at distances up to 30 cm from the ion source. A variety of sputtering applications were undertaken with a small 10 cm ion source to better understand the ion source requirements in these applications. The results of these experimental studies are also included. Author

**N77-23385\*** Stanford Research Inst., Menlo Park, Calif.  
**PHOTOCONDUCTIVITY OF HIGH VOLTAGE SPACE INSULATING MATERIALS: MEASUREMENTS WITH METAL ELECTRODES** Interim Technical Report, 1 Jul. 1974 - 1 Apr. 1975

H T Coffey and J E Nanevitz Apr. 1975 31 p  
 (Contract NAS3-18912 SRI Proj 3445)  
 (NASA-CR-152839: ITR-1) Avail NTIS HC A03/MF A01 CSCL 09C

The electrical conductivities of high voltage insulating materials were measured in the dark and under various intensities of illumination. The materials investigated included FEP Teflon, Kapton-H, fused quartz, and parylene. Conductivities were determined as functions of temperature between 22 and 100 C and light intensity between 0 and 2.5 kW/m<sup>2</sup>. The thickness dependence of the conductivity was determined for Teflon and Kapton, and the influence of spectral wavelengths on the conductivity was determined in several cases. All measurements were made in a vacuum to simulate a space environment, and all samples had metallic electrodes. The conductivity of Kapton was permanently increased by exposure to light, changes as great as five orders of magnitude were observed after six hours of illumination. Author

**N77-23386\*** Litton Industries, San Carlos, Calif. Electron Tube Div.

**A 200 WATT TRAVELING WAVE-TUBE FOR THE COMMUNICATIONS TECHNOLOGY SATELLITE** Final Report  
 C L Jones Nov. 1976 238 p refs  
 (Contract NAS3-15830)  
 (NASA-CR-135029) Avail: NTIS HC A11/MF A01 CSCL 09A

The results of the design, development, and test of experimental and production units of PPM focused traveling wave tube that produces 225 watts of CW RF power over 85 MHz centered at 12.080 GHz are presented. The tube uses a coupled cavity RF circuit with a velocity taper for greater than 26 percent basic efficiency. Overall efficiency of 50 percent is achieved by the incorporation of a multistage depressed collector designed at NASA Lewis Research Center. The collector is cooled by direct radiation to deep space. The tube was designed to be used for broadcasting power transmission from a satellite. Author

**N77-28404\*** Westinghouse Electric Corp., Lima, Ohio.  
 Aerospace Electrical Div.  
**AEROSPACE TECHNOLOGY DEVELOPMENT OF SOLID STATE REMOTE POWER CONTROLLERS FOR 300 VDC WITH CURRENT RATINGS OF ONE AND TWO AMPERES, ONE TYPE HAVING CURRENT LIMITING**  
 W. W. Billings Apr. 1977 182 p ref  
 (Contract NAS3-20083)  
 (NASA-CR-135199: WAED-77-01E) Avail: NTIS HC A09/MF A01 CSCL 09C

Two types of transistor remote power controllers for spacecraft distribution systems have been developed, built, and fully tested. Simple, efficient, reliable and relatively low cost designs are described with test results. Each design provides overcurrent protection through an inverse trip out function with

a fail safe device back up. All designs have demonstrated step applied fault capability with a fast risetime power source. They have also been demonstrated for power quality, transient immunity, and compatibility with anticipated loads. Author

**N77-28405\*** Westinghouse Electric Corp., Lima, Ohio.  
 Aerospace Electrical Div.  
**AEROSPACE TECHNOLOGY DEVELOPMENT OF THREE TYPES OF SOLID STATE REMOTE POWER CONTROLLERS FOR 120 VDC WITH CURRENT RATINGS OF FIVE AND THIRTY AMPERES, ONE TYPE HAVING CURRENT LIMITING** Technical Report, Jul. 1973 - May 1977  
 J. T. Mitchell Apr. 1977 372 p  
 (Contract NAS3-17771)  
 (NASA-CR-135216: WAED-77-05E) Avail: NTIS HC A16/MF A01 CSCL 09C

Three types of transistor remote power controllers for spacecraft distribution systems have been developed, built and fully tested. Simple, reliable, efficient and relatively low cost designs are described with test results. Each design provides an inverse, trip-off protection for overloads. All designs have demonstrated compatibility with 4000 ampere, low inductance sources and comply with basic requirements. These highly miniaturized units feature mounting tabs for efficient heat transfer to the heat sinks. Inverted type construction provides top located terminals for easy wiring access. These units are hermetically sealed and of flight worthy quality. Author

**N77-30368\*** Westinghouse Electric Corp., Lima, Ohio.  
 Aerospace Electrical Div.  
**AEROSPACE TECHNOLOGY DEVELOPMENT OF SOLID STATE REMOTE POWER CONTROLLERS FOR 300 VDC WITH CURRENT RATINGS OF ONE AND TWO AMPERES, ONE TYPE HAVING CURRENT LIMITING**  
 W W Billings Jun. 1977 183 p  
 (Contract NAS3-20083)  
 (NASA-CR-135199: WAED-77-01E) Avail: NTIS HC A09/MF A01 CSCL 09A

Two types of transistor remote power controllers (RPC) for 270/300 Vdc spacecraft distribution systems were developed, built and fully tested. Simple, efficient (99%), reliable and relatively low cost RPC designs are described with test results. The 1 ampere design (TYPE A) is capable of limiting maximum overload current to 3 amperes for 1 second and the 2 ampere non current limiting design (Type 2); provides instant tripping at 10 amperes and above. Each design provides overcurrent protection through an inverse 1 squared t trip out function with a fail-safe device back-up. All designs have demonstrated step applied fault capability with a fast risetime (low inductance) power source. They have also been demonstrated to meet MIL-STD-704B specification for power quality - or - 1000V transient immunity, and compatibility with anticipated loads. An evaluation of fuse operations with 300Vdc/4000A sources has shown the compliance of two candidate types to RPC applications. The study of technology limitations revealed several areas that if implemented will improve performance, cost, reliability capability and size of not only high voltage DC RPC's but also lower voltage devices. Author

**N77-30369\*** Westinghouse Electric Corp., Lima, Ohio.  
 Aerospace Electrical Div.  
**AEROSPACE TECHNOLOGY DEVELOPMENT OF THREE TYPES OF SOLID STATE REMOTE POWER CONTROLLERS FOR 120 VDC WITH CURRENT RATINGS OF FIVE AND THIRTY AMPERES, ONE TYPE HAVING CURRENT LIMITING**  
 J T Mitchell Jun. 1977 272 p ref  
 (Contract NAS3-17771)  
 (NASA-CR-135216: WAED-77-05E) Avail: NTIS HC A12/MF A01 CSCL 09A

Three types of transistor Remote Power Controllers (RPC's) for 120V spacecraft distribution systems have been developed, built and fully tested. Simple, efficient (99%), reliable, and relatively low cost RPC designs are described with test results. Each design

provides tripoff protection for overloads. All designs have demonstrated compatibility with 4000 Ampere, low inductance sources. Significant tests performed were: static, dynamic, temperature, faults, transients, and load compatibility performances. Author

**N77-31406\*** Westinghouse Research Labs., Pittsburgh, Pa.  
**DEVELOPMENT OF A 1000V, 200A, LOW-LOSS, FAST-SWITCHING, GATE-ASSISTED TURN-OFF THYRISTOR**  
 Final Report  
 E. S. Schlegel, L. R. Lowry, and D. L. Moore 2 Sep. 1977  
 111 p refs  
 (Contract NAS3-16801)  
 (NASA-CR-134951; Rept-77-9F5-GATT-R1) Avail: NTIS  
 HC A08/MF A01 CSCL 09A

The results of a program to develop a fast high power thyristor that can operate in switching circuits at frequencies of 10 to 20 kHz with very low power loss are given. Feasibility was demonstrated for a thyristor that blocks 1000V forward and reverse, conducts 200A, turns on in little more than 2 more microseconds with only 2A of gate drive, turns off in 3 microseconds with 2A of gate assist current and has an energy dissipation of only 12 mJ per pulse for a 20 microsecond half sine wave 200A pulse. Data were generated that clearly showed the tradeoffs that can be made between the turn off time and forward drop. The understanding of this relationship is necessary in the selection of deliverable thyristors with turn off times up to 7 microseconds to give improved efficiency in a series resonant dc to dc inverter application. Author

**N77-32398\*** TRW Systems Group, Redondo Beach, Calif.  
**DEVELOPMENT OF A STANDARDIZED CONTROL MODULE FOR dc-TO-dc CONVERTERS**  
 Y. Yu, R. I. Iwens, F. C. Lee, and L. Y. Inouye 30 Aug. 1977  
 154 p refs  
 (Contract NAS3-18918)  
 (NASA-CR-135072; TRW-26629.000) Avail: NTIS  
 HC A08/MF A01 CSCL 09A

The electrical performance of a power processor depends on the quality of its control system. Most of the existing control circuits suffer one or more of the following imperfections that tend to restrict their respective utility: (1) inability to perform different modes of duty cycle control; (2) lack of immunity to output filter parameter changes, and (3) lack of capability to provide power component stress limiting on an instantaneous basis. The three lagging aspects of existing control circuits have been used to define the major objectives of the current Standardized Control Module (SCM) Program. Detailed information on the SCM functional block diagram, its universality, and performance features, circuit description, test results, and modeling and analysis efforts are presented. Author

**A77-16607\*** Physical properties of thin-film field emission cathodes with molybdenum cones. C. A. Spindt, I. Brodie, L. Humphrey, and E. R. Westerberg (Stanford Research Institute, Menlo Park, Calif.). *Journal of Applied Physics*, vol. 47, Dec. 1976, p. 5248-5263. 37 refs. Grant No. DAHC04-73-C-0007; Contract No. NAS3-18903.

Field emission cathodes fabricated using thin-film techniques and electron beam microlithography are described, together with effects obtained by varying the fabrication parameters. The emission originates from the tip of molybdenum cones that are about 1.5 micron tall with a tip radius around 500 Å. Such cathodes have been produced in closely packed arrays containing 100 and 5000 cones as well as singly. Maximum currents in the range 50-150 microamp per cone can be drawn. Life tests with the 100-cone arrays drawing 2 mA total emission (or 3 A per sq cm) have proceeded in excess of 7000 hr with about a 10% drop in emission current. Studies are presented of the emission characteristics and current fluctuation phenomena. It is tentatively concluded that the emission arises from only one or a few atomic sites on the cone tips. (Author)

**A77-32237\*** Gate assisted turn-off thyristor with cathode shunts and dynamic gate. E. S. Schlegel and D. J. Page (Westinghouse Research Laboratories, Pittsburgh, Pa.). In: *International Electron Devices Meeting*, Washington, D.C., December 5-8, 1976, Technical Digest. Meeting sponsored by the Institute of Electrical and Electronics Engineers, New York, Institute of Electrical and Electronics Engineers, Inc., 1976, p. 487-490. 7 refs. Contract No. NAS3-16801.

A 1,000-V, 200-A gate-assisted turn-off thyristor (GATT) is described, whose design features include an interdigitated shunted cathode, a dynamic gate, a means for optimizing the carrier lifetime level, and a bypass diode. The device physics of gate-assisted turn-off are reviewed. Based on this, improvements in the design are described. It is shown that a prime failure mode can be eliminated and that the gate-assist signal voltage can be substantially decreased by employing a shunted cathode emitter. The test data show excellent turn-on characteristics due to the dynamic gate and the long perimeter of the edge of the main cathode. Turn-off times as short as 3 microsec are obtained. The combination of controlling the carrier lifetime with a precisely controlled and easily variable irradiation dose of high energy electrons with gate assist current provides for simple, precision tailoring of the device characteristics to the intended application. (Author)

**A77-40952\*** A general unified approach to modelling switching-converter power stages. R. D. Middlebrook and S. Cuk (California Institute of Technology, Pasadena, Calif.). In: *Power Electronics Specialists Conference*, Cleveland, Ohio, June 8-10, 1976, Record. (A77-40951 19-33) New York, Institute of Electrical and Electronics Engineers, Inc., 1975, p. 18-34. 10 refs. Contract No. NAS3-19690.

A method for modeling switching-converter power stages is developed, whose starting point is the unified state-space representation of the switched networks and whose end result is either a complete state-space description or its equivalent small-signal low-frequency linear circuit model. A new canonical circuit model is proposed, whose fixed topology contains all the essential input-output and control properties of any dc-to-dc switching converter, regardless of its detailed configuration, and by which different converters can be characterized in the form of a table conveniently stored in a computer data bank to provide a useful tool for computer aided design and optimization. The new canonical circuit model predicts that, in general, switching action introduces both zeros and poles into the duty ratio to output transfer function in addition to those from the effective filter network. (Author)



# 34 FLUID MECHANICS AND HEAT TRANSFER

Includes boundary layers; hydrodynamics; fluidics; mass transfer; and ablation cooling.

For related information see also 02 Aerodynamics and 77 Thermodynamics and Statistical Physics.

**N77-14377\*** National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio.

## THREE-DIMENSIONAL POTENTIAL FLOW OVER HILLS AND OVAL MOUNDS

Robert Siegel Washington Dec. 1976 36 p refs (NASA-TN-D-8375; E-8769) Avail: NTIS HC A03/MF A01 CSCL 20D

An analysis was made of the potential flow behavior for an initially uniform flow passing over a single axisymmetric hill, an oval mound, and a combination of two hills. Small perturbation theory was used, and the resulting Laplace equation for the perturbation velocity potential was solved by using either a product solution or a Green's function. The three dimensional solution is of interest in calculating the pressure distribution around obstacles, the flow of pollutants carried by the wind, and the augmentation of wind velocity for windmill siting. The augmentation in velocity at the top of a hill was found to be proportional to the hill height relative to a characteristic width dimension of the hill. An axisymmetric hill produced about 20 percent less velocity increase than a two dimensional ridge having the same cross-sectional profile. Author

**N77-18343\*** National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio.

## MAGNETIC HEAT PUMPING Patent Application

Gerald V. Brown, inventor (to NASA) Filed 30 Nov. 1976 21 p (NASA-Case-LEW-12508-1; US-Patent-Appl-SN-746580) Avail: NTIS HC A02/MF A01 CSCL 20D

The magnetic heat pumping method employs ferromagnetic or ferrimagnetic elements, preferably a rare earth based material, such as gadolinium, and preferably employs a regenerator. The temperature and applied magnetic field of the element are controlled to cause the state of the element as represented on a temperature-magnetic entropy diagram repeatedly to traverse a loop. The loop may have a first portion of concurrent substantially isothermal or constant temperature and increasing applied magnetic field, a second portion of lowering temperature and constant applied magnetic field, a third portion of isothermal and decreasing applied magnetic field, and a fourth portion of increasing temperature and constant applied magnetic field. Other loops may be four-sided, with, for example, two isotherms and two adiabats (constant magnetic entropy portions). A regenerator may be employed to enhance desired cooling or heating effects, with varied magnetic fields or varying temperatures including three-sided figures traversed by the representative point. NASA

**N77-17390\*** National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio.

## AN EXPERIMENTAL STUDY OF REACTIVE TURBULENT MIXING

L. P. Cooper, C. J. Marek, and R. A. Strehlow 1977 3\* p refs Presented at 15th Aerospace Sci. Meeting, Los Angeles, 24-26 Jan. 1977; sponsored by AIAA (NASA-TM-X-73579; E-9041) Avail: NTIS HC A03/MF A01 CSCL 20D

An experimental study of two coaxial gas streams, which react very rapidly, was performed to investigate the mixing characteristics of turbulent flow fields. The center stream consisted of a CO-N<sub>2</sub> mixture and the outer annular stream consisted of air vitiated by H<sub>2</sub> combustion. The streams were at equal velocity (50 m/sec) and temperature (1250 K). Turbulence measurements were obtained using hot film anemometry. A sampling probe was used to obtain time averaged gas compositions. Six different turbulence generators were placed in the

annular passage to alter the flow field mixing characteristics. The turbulence generators affected the bulk mixing of the streams and the extent of CO conversion to different degrees. The effects can be related to the average eddy size (integral scale) and the bulk mixing. Higher extents of conversion of CO to CO<sub>2</sub> were found by increasing the bulk mixing and decreasing the average eddy size. Author

**N77-23408\*** National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio.

## INTERACTIVE CALCULATION PROCEDURE FOR SUPERSONIC FLOWS Ph.D. Thesis Case Western Reserve Univ., 1976. Final Report

Yehuda Tassa (Case Western Reserve Univ.), Bernhard H. Anderson, and Eli Reshotko (Case Western Reserve Univ.) May 1977 170 p refs (Grant NGR-36-027-064)

(NASA-TM-X-73653; FTAS/TR-76-125) Avail: NTIS HC A08/MF A01 CSCL 20D

An interactive procedure was developed for supersonic viscous flows that can be used for either two-dimensional or axisymmetric configurations. The procedure is directed to supersonic internal flows as well as those supersonic external flows that require consideration of mutual interaction between the outer flow and the boundary layer flow. The flow field is divided into two regions: an inner region which is highly viscous and mostly subsonic and an outer region where the flow is supersonic and in which viscous effects are small but not negligible. For the outer region a numerical solution is obtained by applying the method of characteristics to a system of equations which includes viscous and conduction transport terms only normal to the streamlines. The inner region is treated by a system of equations of the boundary layer type that includes higher order effects such as longitudinal and transverse curvature and normal pressure gradients. These equations are coupled and solved simultaneously in the physical coordinates by using an implicit finite difference scheme. This system can also be used to calculate laminar and turbulent boundary layers using a scalar eddy viscosity concept. Author

**N77-24426\*** National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio.

## FILM COOLING ON THE PRESSURE SURFACE OF A TURBINE VANE

James W. Gauntner and Herbert J. Gladden May 1977 17 p refs

(NASA-TM-X-3536; E-8764) Avail: NTIS HC A02/MF A01 CSCL 20D

Film-cooling-air ejection from the pressure surface of a turbine vane was investigated, and experimental data are presented. This investigation was conducted in a four-vane cascade on a J75-size turbine vane that had a double row of staggered holes in line with the primary flow and located downstream of the leading edge region. The results showed that: (1) the average effectiveness of film-convection cooling was higher than that of either film cooling or convection cooling separately; (2) the addition of small quantities of film-cooling air always increased the cooling effectiveness relative to the zero-injection case; however, (3) the injected film must exceed a certain threshold value to obtain a beneficial effect of film cooling relative to convection cooling alone. Author

**N77-25454\*** National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio.

## FLOW AND HEAT TRANSFER IN A CURVED CHANNEL

Paul F. Brinich and Robert W. Graham Washington May 1977 40 p refs (NASA-TN-D-8464; E-9027) Avail: NTIS HC A03/MF A01 CSCL 20D

Flow and heat transfer in a curved channel of aspect ratio 6 and inner- to outer-wall radius ratio 0.96 were studied. Secondary currents and large longitudinal vortices were found. The heat-transfer rates of the outer and inner walls were independently controlled to maintain a constant wall temperature.

Heating the inner wall increased the pressure drop along the channel length, whereas heating the outer wall had little effect. Outer-wall heat transfer was as much as 40 percent greater than the straight-channel correlation, and inner-wall heat transfer was 22 percent greater than the straight-channel correlation.

Author

**N77-28431\*** National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio.

**TWO PHASE CHOKE FLOW IN TUBES WITH VERY LARGE L/D**

R. C. Hendricks and R. J. Simoneau Aug. 1977 23 p refs Presented at the 1977 Cryog. Eng. Conf., Boulder, Colo., 2-5 Aug. 1977; sponsored by NBS

(NASA-TM-73728; E-9279) Avail: NTIS HC A02/MF A01 CSCL 20D

Data were obtained for two phase and gaseous choked flow nitrogen in a long constant area duct of 16200 L/D with a diverging diffuser attached to the exit. Flow rate data were taken along five isotherms (reduced temperature of 0.81, 0.96, 1.06, 1.12, and 2.34) for reduced pressures to 3. The flow rate data were mapped in the usual manner using stagnation conditions at the inlet mixing chamber upstream of the entrance length. The results are predictable by a two phase homogeneous equilibrium choking flow model which includes wall friction. A simplified theory which in essence decouples the long tube region from the high acceleration choking region also appears to predict the data reasonably well, but about 15 percent low.

Author

**N77-28435\*** National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio.

**THERMALLY DRIVEN OSCILLATIONS AND WAVE MOTION OF A LIQUID DROP**

K. J. Baumeister, R. C. Hendricks, and G. J. Schoessow Aug. 1977 12 p refs Presented at Natl. Heat Transfer Conf., Salt Lake City, Utah, 14-17 Aug. 1977; sponsored by Am. Inst. of Chem. Engineers

(NASA-TM-X-73625; E-9117) Avail: NTIS HC A02/MF A01 CSCL 20D

In the state of Leidenfrost boiling, liquid drops are observed to vibrate in a variety of modal patterns. Theories are presented which predict the frequency of oscillation and show that the observed modal patterns of drops correspond to the minimum energy oscillatory excitation state. High-speed photographic techniques were used to record these motions and substantiate the theories. An incipient temperature was also found for water drops in film boiling below which free oscillations do not exist. In addition to these oscillations, photographic sequences are presented which show that wave motion can exist along the circumference of the drop. Following the study of free oscillations, the system was mounted on a shaker table and the drop subjected to a range of forced frequencies and accelerations.

Author

**N77-28436\*** National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio.

**ESTIMATING SURFACE TEMPERATURE IN FORCED CONVECTION NUCLEATE BOILING: A SIMPLIFIED METHOD**

R. C. Hendricks and S. S. Papell Aug. 1977 8 p refs Presented at 1977 Cryogenic Engr. Conf., Boulder, Colo., 2-5 Aug. 1977; sponsored by NBS

(NASA-TM-X-73688; E-9223) Avail: NTIS HC A02/MF A01 CSCL 20D

During a test program to investigate low-cycle thermal fatigue, 21 of 22 cylindrical test sections of a cylindrical rocket thrust chamber were thermally cycled to failure. Cylinder liners were fabricated from OFHC copper, Amzirc, and NARloy-Z. The cylinders were fabricated by milling cooling channels into the liner and closing out the backside with electrodeposited copper. The tests were conducted at a chamber pressure of 4.14 MN/sq m (600 psia) and an oxidant-fuel ratio of 8.0 using hydrogen-oxygen as propellants. The average throat heat flux was 54 MW/sq m (33 Btu/sq in./sec). All of the failures were characterized by a

thinning of the cooling channel wall and eventual failure by tensile rupture. The 1/2-hard Amzirc material showed little improvement in cyclic life when compared with OFHC copper, while the NARloy-Z and aged Amzirc materials had the best cyclic life characteristics. One OFHC copper cylinder was thermally cycled 2044 times at a steady-state hot-gas-side wall temperature of 514 K (925 R) without failing.

Author

**N77-30413\*** National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio.

**LIQUID JET IMPINGEMENT NORMAL TO A DISK IN ZERO GRAVITY Ph.D. Thesis Toledo Univ.**

Thomas L. Labus Aug. 1977 118 p refs (NASA-TP-1017; E-8668) Avail: NTIS HC A06/MF A01 CSCL 20D

The free surface shapes of circular liquid jets impinging normal to sharp-edged disks in zero gravity are determined. Zero gravity drop tower experiments yielded three distinct flow patterns that were classified in terms of the relative effects of surface tension and inertial forces. An order of magnitude analysis was conducted that indicated regions where viscous forces were not significant in the computation of free surface shapes. The free surface analysis was simplified by transforming the governing potential flow equations and boundary conditions into the inverse plane, where the stream function and velocity potential became the coordinates. The resulting nonlinear equations were solved by standard finite difference methods, and comparisons were made with the experimental data for the inertia dominated regime.

Author

**N77-31441\*** National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio.

**REPRESENTATION OF TURBULENT SHEAR STRESS BY A PRODUCT OF MEAN VELOCITY DIFFERENCES**

Willis H. Braun Sep. 1977 50 p refs (NASA-TP-1029; E-9057) Avail: NTIS HC A03/MF A01 CSCL 20D

A quadratic form in the mean velocity for the turbulent shear stress is presented. It is expressed as the product of two velocity differences whose roots are the maximum velocity in the flow and a cutoff velocity below which the turbulent shear stress vanishes. Application to pipe and channel flows yields the centerline velocity as a function of pressure gradient, as well as the velocity profile. The flat plate, boundary-layer problem is solved by a system of integral equations to obtain friction coefficient, displacement thickness, and momentum-loss thickness. Comparisons are made with experiment.

Author

**N77-32431\*** National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio.

**MEAN VELOCITY, TURBULENCE INTENSITY, AND SCALE IN A SUBSONIC TURBULENT JET IMPINGING NORMAL TO A LARGE FLAT PLATE**

Donald R. Boldman and Paul F. Brinich Sep. 1977 35 p refs (NASA-TP-1037; E-8998) Avail: NTIS HC A03/MF A01 CSCL 20D

To explain the increase in noise when a jet impinges on a large flat plate, mean velocity, turbulence intensity, and scale were measured at nominal nozzle-exit velocities of 61, 138, and 192 meters per second with the plate located 7.1 nozzle-exit diameters from the nozzle. The maximum turbulence intensities in free and impinging jets were about the same; however, the integral length scale near the plate surface was only about one-half the free jet scale. The measured intensities and length scales, in conjunction with a contemporary theory of aerodynamic noise, provided a good explanation for the observed increase in noise associated with the impinging jet. An increase in the volume of highly turbulent flow could be the principal reason for the increase in noise.

Author

**N77-32432\*** National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio.

**EFFECT OF FIN PASSAGE LENGTH ON OPTIMIZATION OF CYLINDER HEAD COOLING FINS**

Robert Siegel and Robert W. Graham. Sep. 1977 34 p refs (NASA-TP-1054; E-9098) Avail: NTIS HC A03/MF A01 CSCL 21A

The heat transfer performance of baffled cooling fins on cylinder heads of small, air-cooled, general-aviation aircraft engines was analyzed to determine the potential for improving cooling fin design. Flow baffles were assumed to be installed tightly against the fin end edges. An ideal baffle configuration for guiding all flow between the fins. A rectangular flow passage is thereby formed between each set of two adjacent fins, the fin base surface, and the baffle. These passages extend around each side of the cylinder head, and the cooling air absorbs heat as it flows within them. For each flow passage length, the analysis was concerned with optimizing fin spacing and thickness to achieve the best heat transfer for each fin width. Previous literature has been concerned mainly with maximizing the local fin conductance and has not considered the heating of the gas in the flow direction, which leads to higher wall temperatures at the fin passage exits. If the fins are close together, there is a large surface area, but the airflow is restricted.

Author

**N77-32434\*** National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio.

**CLOSED LOOP SPRAY COOLING APPARATUS Patent Application**

Donald L. Alger, William Schwab, and Edward R. Furman, inventors (to NASA) Filed 31 Aug. 1977 11 p (NASA-Case-LEW-11981-2; US-Patent-Appi-SN-829315) Avail: NTIS HC A02/MF A01 CSCL 20D

A closed loop apparatus for spraying coolant against the back of a radiation target is described. The coolant is circulated through a closed loop with a bubble of inert gas being maintained around the spray. Mesh material is disposed between the bubble and the surface of the liquid coolant which is below the bubble at a predetermined level. In a second embodiment no inert gas is used, the bubble consisting of vapor produced when the coolant is sprayed against the target.

NASA

**N77-32435\*** National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio.

**MAGNETIC HEAT PUMPING Patent Application**

Gerald V. Brown, inventor (to NASA) Filed 31 Aug. 1977 21 p

(NASA-Case-LEW-12508-2; US-Patent-Appi-SN-829319) Avail: NTIS HC A02/MF A01 CSCL 20D

A method of magnetic heat pumping is provided which is applicable at room temperature and below. The method employs a ferromagnetic or ferrimagnetic element whose state, as represented on a temperature-magnetic entropy diagram, repeatedly is caused to traverse a loop. This method operates as a result of temperature and magnetic field control. A regenerator is utilized to enhance desired cooling or heating effects.

NASA

**N77-33444\*** National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio.

**VAPOR INGESTION IN CENTAUR LIQUID-HYDROGEN TANK**

Eugene P. Symons. Oct. 1977 31 p refs (NASA-TP-1061; E-9234) Avail: NTIS HC A03/MF A01 CSCL 20D

Vapor ingestion phenomena were investigated using scale models of the Centaur liquid hydrogen tank to determine the height of the surface of the liquid when vapor is initially ingested into the tank outlet. Data are compared with an analysis and, in general, the agreement is very good. Predictions are presented for minimum liquid levels required in the Centaur liquid hydrogen tank in order to prevent vapor ingestion when restarting the engines in space and the quantities of liquid remaining in the tank at vapor ingestion during main engine firing.

Author

**A77-13378\*** Influence of heat transfer on the stability of parallel flow between concentric cylinders. Y. K. Choo (NASA, Lewis Research Center, Cleveland, Ohio) and M. C. Potter (Michigan State University, East Lansing, Mich.). *Physics of Fluids*, vol. 19, Nov. 1976, p. 1676-1679. 6 refs.

The stability of the parallel flow of water between concentric cylinders at different temperatures is investigated for infinitesimal velocity and pressure disturbances. Primary interest is in the effect of heat transfer and the radius ratio  $a/b$  on the critical point of the neutral stability curve. The results indicate a strong dependence of the critical eigenvalues on both the heat transfer and the radius ratio. The critical Reynolds number of the nonisothermal flow appears to approach a finite value as the inner radius approaches zero (pipe flow) by showing an inflection point on the curve of critical Reynolds number vs  $a/b$ .

(Author)

**A77-14533\*** Transport processes in boiling and two-phase systems, including near-critical fluids. Y.-Y. Hsu (U.S. Nuclear Regulatory Commission, Reactor Safety Research Div., Washington, D.C.) and R. W. Graham (NASA, Lewis Research Center, Cleveland, Ohio). Washington, D.C., Hemisphere Publishing Corp.; New York, McGraw-Hill Book Co., 1976. 559 p. 688 refs. \$28.50.

Aspects of pool boiling are considered, taking into account nucleate boiling, the nucleate boiling mechanism, film boiling, and the transition between nucleate and film boiling. The characteristics of two-phase flow are also investigated, giving attention to two-phase flow parameters and equations, the flow pattern in two-phase flow, the pressure drop in two-phase flow, heat transfer in two-phase flow, two-phase flow dynamics, the boiling crisis in two-phase flow, the critical flow rate, the propagation of the pressure pulse and the sonic velocity in two-phase media, instrumentation for two-phase flow, and geometry and field effects on boiling and two-phase flow. Near-critical fluids are also considered.

G.R.

**A77-16621\*** Derivation of the Navier-Stokes equation. R. G. Deissler (NASA, Lewis Research Center, Cleveland, Ohio). *American Journal of Physics*, vol. 44, Nov. 1976, p. 1128-1130. 10 refs.

The proposed approach to the derivation of the Navier-Stokes equation is thought to be more plausible and easier to understand than other derivations that can be found in works on fluid mechanics. The tensor character of the stress is central to the derivation. In particular, a linear relation between stress and strain rate is assumed only for the shear, rather than for the full stress tensor as is done in most other derivations. An assumption for the shear is naturally simpler and easier to verify experimentally. The use of tensor analysis is shown to greatly simplify the derivation.

V.P.

**A77-19984\*** # An experimental study of reactive turbulent mixing. L. P. Cooper, C. J. Marek (NASA, Lewis Research Center, Cleveland, Ohio), and R. A. Strehlow (NASA, Lewis Research Center, Cleveland, Ohio; Illinois, University, Urbana, Ill.). *American Institute of Aeronautics and Astronautics, Aerospace Sciences Meeting, 15th, Los Angeles, Calif., Jan. 24-26, 1977, Paper 77-186*. 30 p. 15 refs.

An experimental study of the turbulent mixing of two coaxial gas streams, which react very rapidly (pseudo-hypergolic chemical kinetics), was performed to investigate the mixing characteristics of turbulent flow fields. The center stream consisted of a CO-N<sub>2</sub> mixture and the outer annular stream consisted of air vitiated by H<sub>2</sub> combustion. The streams were at equal velocity (50 m/sec) and temperature (1280 K). Turbulence measurements were obtained using hot film anemometry. A sampling probe was used to obtain time averaged gas compositions. Six different turbulence generators were placed in the annular passage to alter the flow field mixing characteristics. The turbulence generators affected the bulk mixing of the streams and the extent of CO conversion to different degrees. The effects can be related to the average eddy size and the bulk mixing. Higher extents of conversion of CO to CO<sub>2</sub> were found by increasing the bulk mixing and decreasing the average eddy size.

(Author)

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**A77-37286 \*** # Two-phase working fluids for the temperature range 100-350 C. E. W. Saaski (Sigma Research, Inc., Richland, Wash.) and L. Tower (NASA, Lewis Research Center, Cleveland, Ohio). *American Institute of Aeronautics and Astronautics, Thermophysics Conference, 12th, Albuquerque, N. Mex., June 27-29, 1977, Paper 77-753*. 8 p. 9 refs. NASA-supported research.

The decomposition and corrosion of two-phase heat transfer liquids and metal envelopes have been investigated on the basis of molecular, bond strengths and chemical thermodynamics. Potentially stable heat transfer fluids for the temperature range 100 to 350 C have been identified, and reflux heat pipe tests initiated with 10 fluids and carbon steel and aluminum envelopes to experimentally establish corrosion behavior and noncondensable gas generation rates.

(Author)

**A77-37280 \*** # Re-entrant groove heat pipe. W. Harwell (Grumman Aerospace Corp., Bethpage, N.Y.), W. B. Kaufman, and L. K. Tower (NASA, Lewis Research Center, Cleveland, Ohio). *American Institute of Aeronautics and Astronautics, Thermophysics Conference, 12th, Albuquerque, N. Mex., June 27-29, 1977, Paper 77-773*. 9 p. 14 refs.

This paper describes theoretical and experimentally verified heat pipe characteristics of an axially grooved aluminum extrusion with a re-entrant groove profile. The extrusion is 13 mm diameter with 20 axial grooves, each groove consisting of a nominal .8 mm diameter channel with a .2 mm wide passageway connecting the channel to the hollow core. A computer program was written to compute the zero gravity heat transport capability of the extrusion. A heat pipe was fabricated and its performance characteristics measured. The characteristics of the pipe with ammonia at 20 C are: zero gravity pumping limit 143 w-meters; static wicking height 21.5 mm; evaporator and condenser coefficients 7300 and 20,500 w/m<sup>2</sup>/sq m C, respectively.

(Author)

**A77-42051 \*** # Optimum step design for centering of pistons moving in an incompressible fluid. I. Etsion (Technion - Israel Institute of Technology, Haifa, Israel) and B. J. Hamrock (NASA, Lewis Research Center, Cleveland, Ohio). *American Society of Mechanical Engineers, Applied Mechanics/Bioengineering/Fluids Engineering Summer Conference, Yale University, New Haven, Conn., June 15-17, 1977, Paper 77-FE-30*. 8 p. 7 refs. Members, \$1 50; nonmembers, \$3.00.

Hydrodynamic effects are analyzed for a stepped piston moving within a tight clearance tube filled with an incompressible fluid. Together with the hydrostatic effects that were analyzed in an earlier paper, a complete solution is obtained and an optimum step design for centering of the piston is suggested. The axial speed resulting from an axial driving force is calculated, and some experimental results for pistons falling in a water filled tube are presented.

(Author)

**A77-46427 \*** # Friction factor for isothermal and non-isothermal flow through porous media. J. C. Koh, J. L. Dutton, B. A. Benson (Boeing Co., Seattle, Wash.), and A. Fortini (NASA, Lewis Research Center, Cleveland, Ohio). *ASME, Transactions, Series C - Journal of Heat Transfer*, vol. 99, Aug. 1977, p. 367-373. 14 refs. Contract No. NAS3-12012.

Measurements were performed to determine the pressure drops for gaseous flow through porous materials of different microstructures, porosities, and thickness under isothermal and non-isothermal conditions at various temperature levels. Results were satisfactorily correlated by a simple equation relating the friction factor to the Reynolds number and porosities.

(Author)

**N77-16344 \*** # Stanford Univ., Calif.  
**HEAT TRANSFER TO A FULL-COVERAGE FILM-COOLED SURFACE WITH 30 DEGREE SLANT-HOLE INJECTION**  
M. E. Crawford, W. M. Kays, and R. J. Moffat Washington NASA Dec. 1976 248 p refs  
(Contract NAS3-14336)  
(NASA-CR-2786; SU-HMT-25) Avail: NTIS HC A11/MF A01 CSCL 20D

Heat transfer behavior was studied in a turbulent boundary layer with full coverage film cooling through an array of discrete holes and with injection 30 deg to the wall surface in the downstream direction. Stanton numbers were measured for a staggered hole pattern with pitch-to-diameter ratios of 6 and 10, an injection mass flux ratio range of 0.1 to 1.3, and a range of Reynolds number  $Re_{sub}$  of 150,000 to 5 million. Air was used as the working fluid, and the mainstream velocity varied from 9.8 to 34.2 m/sec (32 to 112 ft/sec). The data were taken for secondary injection temperature equal to the wall temperature and also equal to the mainstream temperature. The data may be used to obtain Stanton number as a continuous function of the injectant temperature by use of linear superposition theory. The heat transfer coefficient is defined on the basis of a mainstream-to-wall temperature difference. This definition permits direct comparison of performance between film cooling and transpiration cooling. A differential prediction method was developed to predict the film cooling data base. The method utilizes a two-dimensional boundary layer program with routines to model the injection process and turbulence augmentation. The program marches in the streamwise direction, and when a row of holes is encountered, it stops and injects fluid into the boundary layer. The turbulence level is modeled by algebraically augmenting the mixing length, with the augmentation keyed to a penetration distance for the injected fluid.

Author

**N77-16288 \*** # Cornell Univ., Ithaca, N.Y.  
**AN EXPERIMENTAL STUDY OF A SELF-CONFINED FLOW WITH RING-VORTICITY DISTRIBUTION** Ph.D. Thesis. Final Report  
Kon-Mang Lin and Franklin K. Moore Aug. 1976 159 p refs  
(Grant NGL-33-010-042)  
(NASA-CR-135104) Avail: NTIS HC A08/MF A01 CSCL 20D

A new form of self-confined flow was investigated in which a recirculation zone forms away from any solid boundary. An inviscid flow analysis indicated that in a purely meridional axisymmetric flow a stationary, spherical, self-confined region should occur in the center of a streamlined divergent-convergent enlargement zone. The spherical confinement region would be at rest and at constant pressure. Experimental investigations were carried out in a specially built test apparatus to establish the desired confined flow. The streamlined divergent-convergent interior shape of the test section was fabricated according to the theoretical calculation for a particular streamline. The required inlet vorticity distribution was generated by producing a velocity profile with a shaped gauze screen in the straight pipe upstream of the test section. Fluid speed and turbulence intensity were measured with a constant-temperature hot-wire anemometer system. The measured results indicated a very orderly and stable flow field.

Author

**N77-16290 \*** # Stanford Univ., Calif.  
**STAN5: A PROGRAM FOR NUMERICAL COMPUTATION OF TWO-DIMENSIONAL INTERNAL AND EXTERNAL BOUNDARY LAYER FLOWS**  
M. E. Crawford and W. M. Kays Washington NASA Nov 1976 136 p refs  
(Contract NAS3-14336; Grants NGR-05-020-134, NSF GK-534; NSF GK-2201)  
(NASA-CR-2742; SU-HMT-23) Avail: NTIS HC A07/MF A01 CSCL 20D

A large variety of two dimensional flows can be accommodated by the program, including boundary layers on a flat plate, flow inside nozzles and diffusers (for a prescribed potential flow distribution), flow over axisymmetric bodies, and developing and fully developed flow inside circular pipes and flat ducts. The flows may be laminar or turbulent, and provision is made to handle transition.

Author

**N77-20375\*** Grumman Aerospace Corp., Bethpage, N.Y.  
**ANALYSIS AND TESTS OF NASA COVERTED GROOVE HEAT PIPE Final Report**  
 Cleveland, Ohio NASA Dec 1976 55 p refs  
 (NASA Order C-65532)  
 (NASA-CR-135156) Avail: NTIS HC A04/MF A01 CSCL 20D

A low-cost thermal control heat pipe having nearly covered grooves extruded in aluminum was developed at NASA. Analytical predictions of transport capability are in excellent agreement with experimental results using ammonia. Axial heat transport predictions as a function of fluid charge are presented also for methane, ethane, propane, and butane. Experimental tests show performance considerably better than that of open groove extruded pipes and comparing favorably with that of more complicated arterial/wick configurations. For ammonia at 20 C, the covert groove pipe obtained a static wicking height of 2.5 cm and an axial heat transport capability of 143 W-m. Author

**N77-21360\*** Aerojet Liquid Rocket Co., Sacramento, Calif.  
**COMBUSTION EFFECTS ON FILM COOLING Final Report, 20 May 1974 - 31 Jul 1975**  
 D. C. Rousar and R. L. Ewen 24 Feb. 1977 195 p refs  
 (Contract NAS3-17813)  
 (NASA-CR-135052) Avail: NTIS HC A09/MF A01 CSCL 20D

The effects of: (1) a reactive environment on film cooling effectiveness, and (2) film cooling on rocket engine performance were determined experimentally in a rocket thrust chamber assembly operating with hydrogen and oxygen propellants at 300 psi chamber pressure. Tests were conducted using hydrogen, helium, and nitrogen film coolants in an instrumented, thin walled, steel thrust chamber. The film cooling, performance loss, and heat transfer coefficient data were correlated with the ALRC entrainment film cooling model which relates film coolant effectiveness and mixture ratio at the wall to the amount of mainstream gases entrained with the film coolant in a mixing layer. In addition, a comprehensive thermal analysis computer program, HOCOOL, was prepared from previously existing ALRC computer programs and analytical techniques. Author

**N77-27347\*** Combustion, Heat and Mass Transfer Ltd., Wimbledon (England).  
**PREDICTION OF HYDRODYNAMICS AND CHEMISTRY OF CONFINED TURBULENT METHANE-AIR FLAMES WITH ATTENTION TO FORMATION OF OXIDES OF NITROGEN**  
 S. Elghobashi, D. B. Spalding, and S. K. Srivatsa Mar 1977 269 p refs  
 (Contract NAS3-18940)  
 (NASA-CR-135179) CHAM-951/2) Avail: NTIS HC A12/MF A01 CSCL 20D

A formulation of the governing partial differential equations for fluid flow and reacting chemical species in a tubular combustor is presented. A numerical procedure for the solution of the governing differential equations is described, and models for chemical equilibrium and chemical kinetics calculations are presented. The chemical equilibrium model is used to characterize the hydrocarbon reactions. The chemical kinetics model is used to predict the concentrations of the oxides of nitrogen. The combustor consists of a cylindrical duct of varying cross sections with concentric streams of gaseous fuel and air entering the duct at one end. Four sample cases with specified inlet and boundary conditions are considered, and the results are discussed. Author

**N77-28430\*** McDonnell-Douglas Astronautics Co., Huntington Beach, Calif.  
**EFFECT OF TRANSIENT LIQUID FLOW ON RETENTION CHARACTERISTICS OF SCREEN ACQUISITION SYSTEMS Final Report, Jun. 1975 - Mar. 1977**  
 E. C. Cady Apr. 1977 206 p  
 (Contract NAS3-19719)  
 (NASA-CR-135218) MDC-G6742) Avail: NTIS HC A01/MF A01 CSCL 20D

A design analysis, is developed based on experimental data, to predict the effects of transient flow and pressure surges (caused either by valve or pump operation, or by boiling of liquids in warm lines) on the retention performance of screen acquisition systems. A survey of screen liquid acquisition system applications was performed to determine appropriate system environment and classification. A screen model was developed which assumed that the screen device was a uniformly distributed composite orthotropic structure, and which accounted for liquid inflow/outflow, gas ingestion quality, screen stress, and liquid spill. A series of 177 tests using 13 specimens (5 screen meshes, 4 screen device construction/backup methods, and 2 orientations) with three test fluids (isopropyl alcohol, Freon 114, and LH2) provided data which verified important features of the screen model and resulted in a design tool which could accurately predict the transient startup performance acquisition devices. Author

**N77-33437\*** Southwest Research Inst., San Antonio, Tex.  
**STUDY OF LIQUID JET IMPINGEMENT ON SCREENS Final Report**  
 Franklin T. Dodge and Randall E. Ricker Sep 1976 50 p refs  
 (Contract NAS3-20086)  
 (NASA-CR-135260) SwRI-02-4492) Avail: NTIS HC A03/MF A01 CSCL 20D

A model is presented for an unconfined flow, such as a free jet, impinging on a screen which incorporates the influence of liquid deflection by the screen. The boundary layer blockage coefficient is introduced. This coefficient depends on the screen weave geometry and the jet impingement angle, and essentially accounts for the increase in fluid particle trajectory length through the screen resulting from the flow deflection. Comparisons were made with previous experimental studies to determine empirical values of the blockage coefficient. It is concluded that the new model reliably predicts the bulk flow and penetration characteristics of an impinging liquid jet interacting with a screen. Author

**A77-13730 \*** Similarity solution of the boundary-layer equations for laser heated flows. P. K. Wu (Physical Sciences, Inc., Woburn, Mass.). *AIAA Journal*, vol. 14, Nov. 1976, p. 1659-1661. 11 refs. Contract No. NAS3-19695.

The laminar boundary-layer equations with local similarity approximation are solved in order to estimate the heat transfer rate to the wall in a laser-heated rocket thruster using pure hydrogen, where the average temperature of the hot plasma core is about 14,000 K and the core Reynolds number based on nozzle throat diameter is about 2000. Under these conditions, the density-viscosity product at the wall can be 10 times the freestream value, and the hydrogen is completely dissociated. Hence the boundary layer equations with variable transport properties are solved by a quasi-linearization technique, and the equilibrium properties of hydrogen are used in the calculations. Velocity profiles are obtained, and the wall shear and wall stagnation enthalpy gradient are plotted against the pressure gradient parameter. P.T.H.

## 35 INSTRUMENTATION AND PHOTOGRAPHY

Includes remote sensors; measuring instruments and gages; detectors; cameras and photographic supplies; and holography.

For aerial photography see 43 *Earth Resources*. For related information see also 06 *Aircraft Instrumentation*, and 19 *Spacecraft Instrumentation*.

**N77-11366\*** National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio.

### SCANNING RADIOMETER FOR MEASUREMENT OF FORWARD-SCATTERED LIGHT TO DETERMINE MEAN DIAMETER OF SPRAY PARTICLES

Donald R. Buchele. Washington. Nov. 1976. 18 p. refs. (NASA-TN-X-3454; E-8818) Avail: NTIS HC A02/MF A01 CSCL 14B

A scanning radiometer is reported that measures forward-scattered light to determine the mean diameter of spray particles. An optical scanning method gives a continuous measurement of the light-scattering angle during spray nozzle tests. A method of calibration and a correction for background light are presented. Mean particle diameters of 10 to 500 micrometers can be measured. Author

**N77-17429\*** National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio.

### LASER DOPPLER VELOCIMETER SYSTEM FOR TURBINE STATOR CASCADE STUDIES AND ANALYSIS OF STATISTICAL BIASING ERRORS

Richard G. Seasholtz. Washington. Feb. 1977. 48 p. refs. (NASA-TN-D-8297; E-8799) Avail: NTIS HC A03/MF A01 CSCL 14B

A laser Doppler velocimeter (LDV) built for use in the Lewis Research Center's turbine stator cascade facilities is described. The signal processing and self contained data processing are based on a computing counter. A procedure is given for mode matching the laser to the probe volume. An analysis is presented of biasing errors that were observed in turbulent flow when the mean flow was not normal to the fringes. Author

**N77-18419\*** National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio.

### ANALYTICAL PROCEDURE FOR EVALUATING SPECKLE-EFFECT INSTRUMENTATION

Arthur J. Decker. Washington. Feb. 1977. 35 p. refs. (NASA-TN-X-3478; E-8924) Avail: NTIS HC A03/MF A01 CSCL 14B

A general analysis suitable for developing speckle effect instruments and a simplified analysis suitable for evaluating laser speckle instrumentation are presented. The simplified analysis is summarized as a list of equations. Several sample applications are discussed. Author

**N77-20406\*** National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio.

### FLOW COMPENSATING PRESSURE REGULATOR Patent Application

Edward F. Baehr, inventor (to NASA). Filed 21 Mar. 1977. 10 p. (NASA-Case-LEW-12718-1; US-Patent-Appl-SN-779428) Avail: NTIS HC A02/MF A01 CSCL 14B

An apparatus for regulating pressure of treatment fluid being supplied to a human or animal eye during ophthalmic procedures such as cataract surgery is disclosed. Flow sensing and pressure regulating diaphragms are provided in a body to modulate a flow control valve. The pressure regulating diaphragm is connected to the flow control valve to open the valve. The flow sensing diaphragm is mechanically connected to the flow control valve and opens it because of the differential pressure on the diaphragm generated by a flow of incoming treatment

fluid through an orifice in the diaphragm. A bypass connection with a variable restriction is connected in parallel relationship to the orifice to provide for adjusting the sensitivity of the flow sensing diaphragm. NASA

**N77-25487\*** National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio.

### MINIATURE DRAG-FORCE ANEMOMETER

Lloyd N. Krause and Gustave C. Fralick. Washington. Jun. 1977. 26 p. refs. (NASA-TM-X-3507; E-9087) Avail: NTIS HC A03/MF A01 CSCL 14B

A miniature drag-force anemometer is described which is capable of measuring dynamic velocity head and flow direction. The anemometer consists of a silicon cantilever beam 2.5 mm long, 1.5 mm wide, and 0.25 mm thick with an integrated diffused strain-gage bridge, located at the base of the beam, as the force measuring element. The dynamics of the beam are like those of a second-order system with a natural frequency of about 42 kHz and a damping coefficient of 0.007. The anemometer can be used in both forward and reversed flow. Measured flow characteristics up to Mach 0.6 are presented along with application examples including turbulence measurements. Author

**N77-27370\*** National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio.

### A LOW COST, PORTABLE INSTRUMENT FOR MEASURING EMITTANCE

G. McDonald. Jun. 1977. 11 p. refs. Presented at the 10th Ann. Meeting of the Intern. Solar Energy Soc., Orlando, Fla., 6-10 Jun. 1977.

(NASA-TM-73697) Avail: NTIS HC A02/MF A01 CSCL 14B

A low cost, portable instrument was developed with which emittance can be measured by comparison to a standard. A reflector collects infrared radiation from a heated sample onto a low mass, black detector and the temperature rise of the black detector is measured with a thermocouple and meter. Graphical examples are presented for determination of emittance from measurements made on a sample at any known temperature. Author

**N77-28488\*** National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio.

### EVALUATION OF TWO GAS-DILUTION METHODS FOR INSTRUMENT CALIBRATION

Albert Evans, Jr. Jul. 1977. 21 p. refs. (NASA-TM-73753; E-9287) Avail: NTIS HC A02/MF A01 CSCL 14B

Two gas dilution methods were evaluated for use in the calibration of analytical instruments used in air pollution studies. A dual isotope fluorescence carbon monoxide analyzer was used as the transfer standard. The methods are not new but some modifications are described. The rotary injection gas dilution method was found to be more accurate than the closed loop method. Results by the two methods differed by 5 percent. This could not be accounted for by the random errors in the measurements. The methods avoid the problems associated with pressurized cylinders. Both methods have merit and have found a place in instrument calibration work. Author

**N77-29470\*** National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio.

### OPTICAL ZERO-DIFFERENTIAL PRESSURE SWITCH AND ITS EVALUATION IN A MULTIPLE PRESSURE MEASURING SYSTEM

J. Anthony Powell. Washington. Aug. 1977. 23 p. refs. (NASA-TM-X-3571; E-9139) Avail: NTIS HC A02/MF A01 CSCL 14B

The design of a clamped-diaphragm pressure switch is described in which diaphragm motion is detected by a simple fiber-optic displacement sensor. The switch was evaluated in a pressure measurement system where it detected the zero crossing

of the differential pressure between a static test pressure and a tank pressure that was periodically ramped from near zero to full-scale gage pressure. With a ramping frequency of 1 hertz and a full-scale tank pressure of 89 N/sq cm gage (100 psig), the switch delay was as long as 2 milliseconds. Pressure measurement accuracies were 0.25 to 0.75 percent of full scale. Factors affecting switch performance are also discussed. Author

**N77-32454\*** National Aeronautics and Space Administration, Lewis Research Center, Cleveland, Ohio.  
**THERMOCOUPLES OF TANTALUM AND RHENIUM ALLOYS FOR MORE STABLE VACUUM-HIGH TEMPERATURE PERFORMANCE Patent**

James F. Morris, inventor (to NASA) Issued 30 Aug. 1977  
 5 p. Filed 6 Nov. 1975 Supersedes N76-13454 (14 - 04, p 0453)

(NASA-Case-LEW-12050-1; US-Patent-4,045,247;  
 US-Patent-Appl-SN-629457; US-Patent-Class-136-240;  
 US-Patent-Class-136-202; US-Patent-Class-136-236R) Avail:  
 US Patent Office CSCL 14B

Thermocouples of the present invention provide stability and performance reliability in systems involving high temperatures and vacuums by employing a bimetallic thermocouple sensor wherein each metal of the sensor is selected from a group of metals comprising tantalum and rhenium and alloys containing only those two metals. The tantalum, rhenium thermocouple sensor alloys provide bare metal thermocouple sensors having advantageous vapor pressure compatibilities and performance characteristics. The compatibility and physical characteristics of the thermocouple sensor alloys of the present invention result in improved emf, temperature properties and thermocouple hot junction performance. The thermocouples formed of the tantalum, rhenium alloys exhibit reliability and performance stability in systems involving high temperatures and vacuums and are adaptable to space propulsion and power systems and nuclear environments. Official Gazette of the U.S. Patent Office

**N77-32481\*** National Aeronautics and Space Administration, Lewis Research Center, Cleveland, Ohio.

**INDICATED MEAN EFFECTIVE PRESSURE INSTRUMENT (IMEP) Patent Application**

William J. Rice, inventor (to NASA) Filed 29 Sep. 1977  
 10 p

(NASA-Case-LEW-12661-1; US-Patent-Appl-SN-637786) Avail:  
 NTIS HC A02/MF A01 CSCL 14B

There is disclosed an apparatus for measuring Indicated Mean Effective Pressure (IMEP) of an internal combustion piston or rotary engine or of an external combustion engine such as a Stirling engine. An optical shaft encoder measures crankshaft angle of the engine. Changes in volume with respect to changes in crankangle of one or more cylinders ( $dV/d\theta$ ) are determined either empirically or algebraically from engine geometry and stored in a memory. As the crank angle changes,  $dV/d\theta$  is read from the memory and multiplied by chamber or cylinder pressure. The product ( $P dV/d\theta$ ) is then added to the total previously accumulated in the cycle. Each time  $\theta$  changes by an amount equal to  $\Delta\theta$ , the process is repeated. At the end of each engine cycle, the total is equal to the IMEP value for that cycle. NASA

**A77-26783\*** Performance of some miniature pressure transducers subjected to high rotational speeds and centripetal accelerations. H. L. Minkin (NASA, Lewis Research Center, Cleveland, Ohio). In: Advances in test measurement. Volume 13. Proceedings of the Twenty-second International Instrumentation Symposium, San Diego, Calif., May 25-27, 1976. (A77-26776 11-35) Pittsburgh, Pa., Instrument Society of America, 1976, p. 55-60.

**A77-26797\*** An automated secondary standard for calibrating liquid flowmeters. H. F. Hobart (NASA, Lewis Research Center, Cleveland, Ohio). In: Advances in test measurement. Volume 13. Proceedings of the Twenty-second International Instrumentation Symposium, San Diego, Calif., May 25-27, 1976. (A77-26776 11-35) Pittsburgh, Pa., Instrument Society of America, 1976, p. 205-209.

A secondary working standard of flow calibration has been developed to be used in place of a primary weight-time standard, and which can thereby effect a 75 percent reduction in calibration time while maintaining acceptable accuracies. The secondary standard uses six previously calibrated turbine-type flowmeters built into two manifold systems containing automatically switched flow valves. The pair of systems is capable of covering the flow range of 0.0004 to 19 1/s (0.007 to 300 gpm) with the uncertainty in volume flow rate not exceeding plus or minus 0.25 percent over the range 0.06 to 19 1/s and not exceeding plus or minus 0.5 percent over the range 0.0004 to 0.06 1/s. Data reduction and plotting of results are by computer. (Author)

**A77-26808\*** A new approach to the pulsed thermocouple for high gas temperature measurements. G. E. Glawo, H. A. Will, and L. N. Krause (NASA, Lewis Research Center, Cleveland, Ohio). In: Advances in test measurement. Volume 13. Proceedings of the Twenty-second International Instrumentation Symposium, San Diego, Calif., May 25-27, 1976. (A77-26776 11-35) Pittsburgh, Pa., Instrument Society of America, 1976, p. 329-335. 8 refs.

Pulsed thermocouple systems can be used to measure gas temperatures above the melting point of the thermocouple by various techniques of short term or intermittent exposure of the thermocouple operating at lower temperatures. This paper describes an approach which uses a thermocouple cooled by a small jet of inert gas. When a measurement is to be made, the cooling jet is turned off and the thermocouple allowed to heat up to near its melting point, at which time the cooling is reapplied. The final temperature which the thermocouple should have attained is then calculated by extrapolating an exponential curve fit to the data. Temperature measurements can be recorded and displayed in near real time by using modern high-speed computing systems to perform these calculations. Examples of the technique applied to high temperature jet engine combustor development are presented. (Author)

**N77-33483\*** Boeing Aerospace Co., Seattle, Wash.  
**DEVELOPMENT OF A HIGH TEMPERATURE CAPACITIVE PRESSURE TRANSDUCER**

Richard L. Egger Oct. 1977 120 p refs

(Contract NAS3-19556)

(NASA-CR-135282; D180-20746-1)

Avail: NTIS

HC A06/MF A01 CSCL 14B

High temperature pressure transducers capable of continuous operation while exposed to 650 C were developed and evaluated over a full-scale differential pressure range of + or - 69 kPa. The design of the pressure transducers was based on the use of a diaphragm to respond to pressure, variable capacitive elements arranged to operate as a differential capacitor to measure diaphragm response and on the use of fused silica for the diaphragm and its supporting assembly. The uncertainty associated with measuring + or - 69 kPa pressures between 20C and 650C was less than + or - 6%. Author



# 36 LASERS AND MASERS

Includes parametric amplifiers.

**N77-11389\*** National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio.

## CONSIDERATIONS TO ACHIEVE DIRECTIONALITY FOR GAMMA RAY LASERS

S. Jha (Cincinnati Univ.) and J. Blum. 1976. 5 p refs Presented at Princeton Univ. Conf. on Partially Ionized Plasmas Including the Third Symp. on Uranium Plasmas, Princeton, N. J., 10-12 Jun. 1976

(Grant NSG-3091)

(NASA-TM-X-73580; E-8933) Avail: NTIS HC A02/MF A01 CSCL 20E

A method of alignment of nuclei for a gamma ray laser and a means of achieving preferential emission of radiation along the crystal axis are discussed. The proposed method of preferential emission of radiation along the aligned needles is to have a symmetric field gradient at the nucleus and a sequence of excited levels of spin and parity  $2(+)$  and  $C(+)$ . The proposed scheme reduces the density of excited states required for lasing and reduces the linewidth due to inhomogeneous broadening. Mossbauer absorption experiments intended to test these ideas are outlined.

Author

**N77-18429\*** National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio.

## IN-SITU LASER RETORTING OF OIL SHALE Patent Application

Harvey S. Bloomfield, inventor (to NASA) Filed 28 Jan. 1977 15 p

(NASA-Case-LEW-12217-1; US-Patent-Appl-SN-763753) Avail: NTIS HC A02/MF A01 CSCL 20E

Oil shale formations were retorted in-situ and gaseous hydrocarbon products recovered by drilling two or more wells into an oil shale formation. After fracturing a region of oil shale formation by directing a high energy laser beam into one of the wells and focussing the laser beam into a region of oil shale formation from a laser optical system, compressed gas was forced into the well which supports combustion in the flame front ignited by laser beam, thereby retorting the oil shale and recovering gaseous hydrocarbon products which permeate through the fractured oil shale from one of the auxiliary wells.

Author

**N77-32476\*** National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio.

## SPATIAL FILTER FOR Q-SWITCHED LASERS Patent

Ralph F. Wuerker (TRW System Group, Redondo Beach, Calif.) and Lee O. Heflinger, inventors (to NASA) (TRW Systems Group, Redondo Beach, Calif.) Issued 23 Aug. 1977 4 p Filed 2 Oct. 1974 Supersedes N74-34010 (12 - 23, p 2839) Sponsored by NASA

(NASA-Case-LEW-12164-1; US-Patent-4,043,874;

US-Patent-Appl-SN-511334; US-Patent-Class-350-162SF) Avail: US Patent Office CSCL 20E

A spatial filtered Q-switched laser system is reported that prevents ionization of air in close proximity to the aperture of the spatial filter. A compound lens system having an astigmatic focus is positioned between the laser and the spatial filter for defocusing the light beam emanating from the laser in the vicinity of the aperture of the spatial filter to an intensity below that which produces ionization of air. The preferred construction of the compound lens system as viewed from the laser comprises a cylindrical lens and a pair of positive lenses.

Official Gazette of the U.S. Patent Office

**A77-28953\***

The NASA high-power carbon dioxide laser - A versatile tool for laser applications. R. B. Lancashire, D. L. Alger, E. J. Manista, J. G. Siaby, J. W. Dunning, and R. M. Stubbs (NASA, Lewis Research Center, Cleveland, Ohio). In: Industrial applications of high power laser technology; Proceedings of the Seminar, San Diego, Calif., August 24, 25, 1976. (A77-28951 12-36) Palos Verdes Estates, Calif., Society of Photo-Optical Instrumentation Engineers, 1976, p. 11-19, 8 refs.

The NASA Lewis Research Center has designed and fabricated a closed-cycle, continuous wave (CW), carbon dioxide (CO<sub>2</sub>) high-power laser to support research for the identification and evaluation of possible high-power laser applications. The device is designed to generate up to 70 kW of laser power in annular-shape beams from 1 to 9 cm in diameter. Electric discharge, either self-sustained or electron-beam-sustained, is used for excitation. This laser facility can be used in two ways. First, it provides a versatile tool on which research can be performed to advance the state-of-the-art technology of high-power CO<sub>2</sub> lasers in such areas as electric excitation, laser chemistry, and quality of output beams, all of which are important whether the laser application is government or industry oriented. Second, the facility provides a well-defined, continuous wave beam for various application experiments, such as propulsion, power conversion, and materials processing.

(Author)

**N77-15381\*** Pratt and Whitney Aircraft, West Palm Beach, Fla. Government Products Div.

## CLOSED-CYCLE GAS DYNAMIC LASER DESIGN INVESTIGATION Final Report

G. W. Ketch and W. E. Young Jan. 1977 176 p refs

(Contract NAS3-19705)

(NASA-CR-135130; PWA-FR-7605)

Avail: NTIS

HC A09/MF A01 CSCL 20E

A conceptual design study was made of a closed cycle gas-dynamic laser to provide definition of the major components in the laser loop. The system potential application is for long range power transmission by way of high power laser beams to provide satellite propulsion energy for orbit changing or station keeping. A parametric cycle optimization was conducted to establish the thermodynamic requirements for the system components. A conceptual design was conducted of the closed cycle system and the individual components to define physical characteristics and establish the system size and weight. Technology confirmation experimental demonstration programs were outlined to develop, evaluate, and demonstrate the technology base needed for this closed cycle GDL system.

Author

**N77-22486\*** Westinghouse Research Labs., Pittsburgh, Pa. DEVELOPMENT OF FAR INFRARED ATTENUATION TO MEASURE ELECTRON DENSITIES IN CW PIN DISCHARGE LASERS Final Report

R. V. Babcock 1977 46 p refs

(Contract NAS3-19702)

(NASA-CR-135154) Avail: NTIS HC A03/MF A01 CSCL 20E

A two beam attenuation technique was devised to measure electron densities 10 to the 9th power to 10 to the 11th power cm<sup>-3</sup> resolved to 1 cm. in a near atmospheric CO<sub>2</sub> laser discharge, using 49F micrometer and 1.220 micrometer radiations from CH<sub>3</sub>F, optically pumped by a CO<sub>2</sub> laser. A far infrared generator was developed which was suitable except for a periodic intensity variation in FIR output deriving from frequency variation of the pump radiation.

Author

**N77-30456\*** Hughes Research Labs., Malibu, Calif. EXCIMER LASERS Annual Report, 30 May 1975 - 10 Jun. 1976

A. J. Palmer, L. D. Hess, and R. R. Stephens Jul. 1976 91 p refs

(Contract NAS3-19707)

(NASA-CR-154843; AR-1) Avail: NTIS HC A05/MF A01 CSCL 20E



A theoretical and experimental investigation into the possibility of achieving CW discharge pumped excimer laser oscillation is reported. Detailed theoretical modeling of capillary discharge pumping of the XeF and KXe and K<sub>2</sub> excimer systems was carried out which predicted the required discharge parameters for reaching laser threshold on these systems. Capillary discharge pumping of the XeF excimer system was investigated experimentally. The experiments revealed a lower excimer level population density than predicted theoretically by about an order of magnitude. The experiments also revealed a fluorine consumption problem in the discharge in agreement with theory. Author

**A77-29069 \* #** Conversion of laser energy to gas kinetic energy. G. E. Caledonia (Physical Sciences, Inc., Woburn, Mass.). *Journal of Energy*, vol. 1, Mar.-Apr. 1977, p. 121-124. 9 refs. Contract No. NAS3-18528.

Techniques for the gas-phase absorption of laser energy with ultimate conversion to heat or directed kinetic energy are reviewed. It is shown that the efficiency of resonance absorption by the vibration/rotation bands of the working gas can be enhanced by operating at sufficiently high pressures so that the linewidths of the absorbing transition exceed the line spacing. Within this limit, the gas can absorb continuously over the full spectral region of the band, and bleaching can be minimized since the manifold of molecular vibrational levels can simultaneously absorb the laser radiation.

(Author)

**A77-37040 \* #** Nozzle flow of laser-heated radiating hydrogen with application to a laser-heated rocket. N. H. Kemp and R. G. Root (Physical Sciences, Inc., Woburn, Mass.). *American Institute of Aeronautics and Astronautics, Fluid and Plasmadynamics Conference, 10th, Albuquerque, N. Mex., June 27-29, 1977, Paper 77-695*, 20 p. 9 refs. Contract No. NAS3-19695.

This paper presents a model for the steady heating of flowing hydrogen by a CW 10.6 micron laser, to consider the feasibility of a laser-heated rocket. The hydrogen flow and the laser beam are parallel, and move into a converging-diverging nozzle. The absorption of laser energy is initiated by a laser-supported combustion wave. The hydrogen is in chemical equilibrium, absorbs laser energy by inverse Bremsstrahlung, and loses energy by radiation. The hydrogen flow was calculated from the rear of the LSC wave to the throat. Estimates of convective heat losses were made using a hydrogen boundary layer analysis. Specific impulse, obtained by expanding isentropically from the throat to 1 atm or a vacuum, varies from 1400 to 3000 s. Radiation losses are 5 to 20%, though the energy fluxes to the walls are quite high. Convective loss estimates are high enough to indicate that coupling to the hot gas flow is required for a 10 kW engine, but not for a 5 MW engine.

(Author)

## 37 MECHANICAL ENGINEERING

Includes auxiliary systems (non-power); machine elements and processes; and mechanical equipment.

**N77-10541\*** National Aeronautics and Space Administration, Lewis Research Center, Cleveland, Ohio.  
**INFLUENCE OF DEBRIS DENT ON EHD LUBRICATION**  
 Lavern D. Wedeven 1975 30 p refs Presented at Joint Lubrication Conf., Boston, 5-7 Oct. 1976; sponsored by Am. Soc. of Lubrication Engr. and ASME  
 (NASA-TM-X-73457; 1-1690) Avail: NTIS HC A03/MF A01 CSCL 131

Film thickness measurements associated with a debris dent have been made with interferometry under static and dynamic conditions. The presence of a debris dent alters the shape of the inlet region so that the local film thickness at the leading edge of the dent can become substantially lower than the trailing edge. The pressure modifications associated with these local elastohydrodynamic (EHD) effects are in line with the frequent occurrence of surface initiated fatigue spalls originating at the trailing edge of debris dents. The effectiveness of the EHD mechanism in reducing the stress concentrations at the shoulders of the dent is related to inlet dimensions and dent size. Author

**N77-11400\*** National Aeronautics and Space Administration, Lewis Research Center, Cleveland, Ohio.  
**ISOTHERMAL ELASTOHYDRODYNAMIC LUBRICATION OF POINT CONTACTS. III: FULLY FLOODED RESULTS**  
 Bernard J. Hamrock and Duncan Dowson (Leeds Univ., Engl.) Washington Oct 1976 40 p refs Presented at the Joint Lubrication Conf., Boston, 5-7 Oct. 1976; Cosponsored by the Am. Soc. of Mechanical Engineers and the Am. Soc. of Lubrication Engineers  
 (NASA-TN-D-8317; E-8712) Avail: NTIS HC A03/MF A01 CSCL 11H

The influence of the ellipticity parameter and the dimensionless speed  $U$ , load  $W$ , and material  $G$  parameters on minimum film thickness was investigated. The ellipticity parameter  $k$  was varied from 1 (a ball-on-plate configuration) to 8 (a configuration approaching a line contact). The dimensionless speed parameter was varied over a range of nearly two orders of magnitude. And the dimensionless load parameter was varied over a range of one order of magnitude. Conditions corresponding to the use of solid materials of bronze, steel, and silicon nitride and lubricants of paraffinic and naphthenic mineral oils were considered in obtaining the exponent on the dimensionless material parameter. Author

**N77-11401\*** National Aeronautics and Space Administration, Lewis Research Center, Cleveland, Ohio.  
**NONAXISYMMETRIC INCOMPRESSIBLE HYDROSTATIC PRESSURE EFFECTS IN RADIAL FACE SEALS**  
 Izhak Etsion Washington Nov 1976 23 p refs  
 (NASA-TN-D-8343; E-8817) Avail: NTIS HC A02/MF A01 CSCL 11A

A flat seal having an angular misalignment is analyzed, taking into account the radial variations in seal clearance. An analytical solution for axial force, tilting moment, and leakage is presented that covers the whole range from zero to full angular misalignment. Nonaxisymmetric hydrostatic pressures due to the radial variations in the film thickness have a considerable effect on seal stability. When the high pressure is on the outer periphery of the seal, both the axial force and the tilting moment are nonrestoring. The case of high-pressure seals where cavitation is eliminated is discussed, and the possibility of dynamic instability is pointed out. Author

**N77-11402\*** National Aeronautics and Space Administration, Lewis Research Center, Cleveland, Ohio.  
**OPTIMUM STEP DESIGN FOR CENTERING OF PISTONS MOVING IN AN INCOMPRESSIBLE FLUID**  
 Izhak Etsion and Bernard J. Hamrock Washington Nov 1976 22 p refs  
 (NASA-TN-D-8345; E-8905) Avail: NTIS HC A02/MF A01 CSCL 131

Hydrodynamic effects are analyzed for a stepped piston moving within a tight clearance tube filled with an incompressible fluid. Hydrostatic effects are analyzed and a complete solution is obtained and an optimum step design for centering of the piston is suggested. The axial speed resulting from an axial driving force is calculated, and some experimental results for pistons falling in a water-filled tube are presented. Author

**N77-12406\*** National Aeronautics and Space Administration, Lewis Research Center, Cleveland, Ohio.  
**EMISSIONS AND PERFORMANCE OF CATALYSTS FOR GAS TURBINE CATALYTIC COMBUSTORS**  
 David N. Anderson 1977 42 p refs Proposed for presentation at 22d Ann. Intern. Gas Turbine Conf., Philadelphia, 27-31 Mar. 1977; sponsored by ASME  
 (NASA-TM-X-73543; E-8975) Avail: NTIS HC A03/MF A01 CSCL 21A

Three noble-metal monolithic catalysts were tested in a 12-centimeter diameter combustion test rig to obtain emissions and performance data at conditions simulating the operation of a catalytic combustor for an automotive gas turbine engine. Tests with one of the catalysts at 800 K inlet mixture temperature 300,000 pa (3 atm) pressure, and a reference velocity (catalyst bed inlet velocity) of 10 m/sec demonstrated greater than 99 percent combustion efficiency for reaction temperatures higher than 1300 K. With a reference velocity of 25 m/sec the reaction temperature required to achieve the same combustion efficiency increased to 1380 K. The exit temperature pattern factors for all three catalysts were below 0.1 when adiabatic reaction temperatures were higher than 1400 K. The highest pressure drop was 4.5 percent at 25 m/sec reference velocity. Nitrogen oxides emissions were less than 0.1 g NO<sub>2</sub>/kg fuel for all test conditions. Author

**N77-13426\*** National Aeronautics and Space Administration, Lewis Research Center, Cleveland, Ohio.  
**AUTOMOTIVE GAS TURBINE FUEL CONTROL Patent Application**  
 H. S. Gold, inventor (to NASA) Filed 8 Nov 1976 28 p  
 (NASA-Case-LEW-12785-1; US-Patent-Appl-SN-739909) Avail: NTIS HC A03/MF A01 CSCL 21E

A fuel control useful for automotive-type gas turbines and particularly advanced gas turbines utilizing variable geometry components to improve mileage and reduce pollution emission is disclosed. The fuel control described compensates for fuel density variations, inlet temperature variations, turbine vane actuation, acceleration, and turbine breaking. These parameters are utilized to control various orifices, spool valves and pistons in a desired manner. NASA

**N77-14484\*** National Aeronautics and Space Administration, Lewis Research Center, Cleveland, Ohio.  
**FATIGUE LIFE ANALYSIS FOR TRACTION DRIVES WITH APPLICATION TO A TOROIDAL TYPE GEOMETRY**  
 John J. Coy, Stuart H. Loewenthal, and Erwin V. Zaretsky Washington Dec. 1976 33 p refs Prepared in cooperation with the US Army Air Mobility R and D Lab.  
 (NASA-TN-D-8362; E-8737) Avail: NTIS HC A03/MF A01 CSCL 131

A contact fatigue life analysis for traction drives was developed which was based on a modified Lundberg-Palmgren theory. The analysis was used to predict life for a cone-roller toroidal traction drive. A 90-percent probability of survival was assumed for the calculated life. Parametric results were presented for life and Hertz contact stress as a function of load, drive ratio, and size. A design study was also performed. The results were compared

to previously published work for the dual cavity toroidal drive as applied to a typical compact passenger vehicle drive train. For a representative duty cycle condition wherein the engine delivers 20 horsepower at 2000 rpm with the vehicle moving at 48.3 km/hr (30 mph) the drive life was calculated to be 19,200 km (11,900 miles).

Author

**N77-16342\*** National Aeronautics and Space Administration, Lewis Research Center, Cleveland, Ohio.

**AIR COOLING OF DISK OF A SOLID INTEGRALLY CAST TURBINE ROTOR FOR AN AUTOMOTIVE GAS TURBINE**  
Herbert J. Gladden Washington Jan 1977 18 p refs  
(NASA-TM-X-3471, E-8902) Avail NTIS HC A02/MF A01 CSCL 20M

A thermal analysis is made of surface cooling of a solid, integrally cast turbine rotor disk for an automotive gas turbine engine. Air purge and impingement cooling schemes are considered and compared with an uncooled reference case. Substantial reductions in blade temperature are predicted with each of the cooling schemes studied. It is shown that air cooling can result in a substantial gain in the stress-rupture life of the blade. Alternatively, increases in the turbine inlet temperature are possible.

Author

**N77-18443\*** National Aeronautics and Space Administration, Lewis Research Center, Cleveland, Ohio.

**CATALYTIC COMBUSTION FOR THE AUTOMOTIVE GAS TURBINE ENGINE**  
David N. Anderson, Robert R. Tacina, and Thaddeus S. Mroz 1977 23 p refs Proposed for presentation at the 4th Intern. Symp. on Automotive Propulsion Systems, Washington, D. C., 17-22 Apr 1977, sponsored by NATO  
(NASA-TM-X-73589) Avail NTIS HC A02/MF A01 CSCL 21A

Fuel injectors to provide a premixed prevaporized fuel-air mixture are studied. An evaluation of commercial catalysts was performed as part of a program leading to the demonstration of a low emissions combustor for an automotive gas turbine engine. At an inlet temperature of 800 K, a pressure of 500,000 Pa and a velocity of 20 m/s a multiple-jet injector produced less than 10 percent variation in Jet-A fuel-air ratio and 100 percent vaporization with less than 0.5 percent pressure drop. Fifteen catalytic reactors were tested with propane fuel at an inlet temperature of 800 K, a pressure of 300,000 Pa and inlet velocities of 10 to 25 m/s. Seven of the reactors had less than 2 percent pressure drop while meeting emissions goals of 13.6 gCO/kg fuel and 1.64 gHC/kg fuel at the velocities and exit temperatures required for operation in an automotive gas turbine engine. NO sub x emissions at all conditions were less than 0.5 ppm. All tests were performed with steady state conditions.

Author

**N77-21441\*** National Aeronautics and Space Administration, Lewis Research Center, Cleveland, Ohio.

**PERFORMANCE OF LARGE-BORE TAPERED-ROLLER BEARINGS UNDER COMBINED RADIAL AND THRUST LOAD AT SHAFT SPEEDS TO 15,000 RPM**  
Richard J. Parker and Hans R. Signer Washington Mar. 1977 25 p refs  
(NASA-TN-D-8404, E-8825) Avail NTIS HC A02/MF A01 CSCL 13I

The performance of 120.65-mm bore tapered roller bearings was investigated at shaft speeds up to 15,000 rpm. Temperature distribution and bearing heat generation were determined as a function of shaft speed, radial and thrust loads, lubricant flow rate, and lubricant inlet temperature. Lubricant was supplied by either jets or by a combination of holes through the cone directly to the cone-rib contact and jets at the roller small-end side. Cone-rib lubrication significantly improved high-speed tapered-roller bearing performance, yielding lower cone-face temperatures and lower power loss and allowing lower lubricant flow rates

for a given speed condition. Bearing temperatures increased with increased shaft speed and decreased with increased lubricant flow rate. Bearing power loss increased with increased shaft speed and increased lubricant flow rate.

Author

**N77-21444\*** National Aeronautics and Space Administration, Lewis Research Center, Cleveland, Ohio.

**ESTIMATION OF STIFFENING EFFECT OF SHAFT AND HOUSING MATERIAL OUTSIDE PROJECTED AREA OF A ROLLING ELEMENT BEARING**  
Christopher M. Taylor Washington Apr 1977 15 p refs  
(NASA-TN-D-8465, E-9034) Avail NTIS HC A02/MF A01 CSCL 13I

In the analysis of distortions occurring in rolling-element bearings, it is common to neglect the stiffening effect of shanking outside the bearing region. The magnitude of such an effect will be dependent primarily on the bearing width-to-bore ratio, the shaft geometry, and the location of the bearing on the shaft. An estimate is given of the stiffening effect for a wide range of these variables. In addition, brief consideration is given to the parallel situation existing at the outer ring housing.

Author

**N77-23487\*** National Aeronautics and Space Administration, Lewis Research Center, Cleveland, Ohio.

**CERAMIC APPLICATIONS IN THE ADVANCED STIRLING AUTOMOTIVE ENGINE**  
William A. Tomazic and James E. Carrelli 1977 13 p Presented at 5th Army Mater. Technol. Conf. Ceramics for High Performance Appl., 2, Newport, R. I., 21-25 Mar. 1977; cosponsored by Army Mater. and Mech. Res. Center and DARPA  
(Contract EC-77-A-31-1011)  
(NASA-TM-X-73632, E-9131, ERDA/NASA-1011/77/2) Avail NTIS HC A02/MF A01 CSCL 21A

The ideal cycle, its application to a practical machine, and the specific advantages of high efficiency, low emissions, multi-fuel capability, and low noise of the Stirling engine are discussed. Certain portions of the Stirling engine must operate continuously at high temperature. Ceramics offer the potential of cost reduction and efficiency improvement for advanced engine applications. Potential applications for ceramics in Stirling engines, and some of the special problems pertinent to using ceramics in the Stirling engine are described. The research and technology program in ceramics which is planned to support the development of advanced Stirling engines is outlined.

Author

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**FRICTION AND WEAR OF SINTERED FIBER-METAL ABRADABLE SEAL MATERIALS**  
Robert C. Bill and Lawrence T. Shiembob (Pratt and Whitney Aircraft, East Hartford, Conn.) 1977 27 p refs Presented at 1977 Intern. Conf. on Wear of Materials, St. Louis, Mo., 25-28 Apr. 1977; sponsored by ASME  
(NASA-TM-X-73650, E-9158) Avail NTIS HC A03/MF A01 CSCL 11A

Three abrasible gas path seal material systems based on a sintered NiCrAlY fibermetal structure were evaluated under a range of wear conditions representative of those likely to be encountered in various knife-edge seal (labyrinth or shrouded turbine) applications. Conditions leading to undesirable wear of the rotating knife were identified and a model was proposed based on thermal effects arising under different rub conditions. It was found, and predicted by the model, that low incursion (plunge) rates tended to promote smearing of the low density sintered material with consequent wear to the knife-edge. Tradeoffs benefits between baseline 19 percent dense material, a similar material of increased density, and a self lubricating coating applied to the 19 percent material were identified based on relative rub tolerance and erosion resistance.

Author

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**CERAMICS FOR THE ADVANCED AUTOMOTIVE GAS TURBINE ENGINE: A LOOK AT A SINGLE SHAFT DESIGN**

Stanley M. Nosek 1977 12 p refs Presented at 5th Army Materials Technol Conf. Ceramics for High Performance Applications, 2, Newport, R.I., 21-25 Mar 1977, sponsored by AMMRC, ERDA, and DARPA (NASA-TM-X-73651, E-9163) Avail NTIS HC A02/MF A01 CSCL 21A

The results of a preliminary analysis of a single shaft regenerative design with a single stage radial turbine are presented to show the fuel economy that can be achieved at high turbine inlet temperatures, with this particular advanced design, if the turbine tip speed and regenerator inlet temperature are not limited. The engine size was 10% up for application to a 3500 lb auto. The fuel economy was analyzed by coupling the engine to the auto through a continuously variable speed-ratio transmission and operating the system at constant turbine inlet temperature over the Composite Driving Cycle. The fuel was gasoline and the analysis was for a 85 F day. With a turbine inlet temperature of 2500 F the fuel economy was 26.2 mpg, an improvement of 18 percent over that of 22.3 mpg with a turbine inlet temperature of 1900 F. The turbine tip speed needed for best economy with the 2500 F engine was 2530 ft/sec. The regenerator temperature was approximately 2200 F at idle. Disk stresses were estimated for one single stage radial turbine and two two-stage radial-axial turbines and compared with maximum allowable stress curves estimated for a current ceramic material. Results show a need for higher Weibull Modulus, higher strength ceramics. Author

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**THERMAL STRESS ANALYSIS OF A GRADED ZIRCONIA METAL GAS PATH SEAL SYSTEM FOR AIRCRAFT GAS TURBINE ENGINES**

Christopher M. Taylor Apr 1977 29 p refs (NASA-TM-X-73658, E-9184) Avail NTIS HC A03/MF A01 CSCL 21E

A ceramic/metallic aircraft gas turbine outer gas path seal designed to enable improved engine performance is studied. Flexible numerical analysis schemes suitable for the determination of transient temperature profiles and thermal stress distributions in the seal are outlined. An estimation of the stresses to which a test seal is subjected during simulated engine deceleration from sea level takeoff to idle conditions is made. Experimental evidence has indicated that the surface layer of the seal is probably subjected to excessive tensile stresses during cyclic temperature loading. This assertion is supported by the analytical results presented. Brief consideration is given to means of mitigating this adverse stressing. Author

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**FINITE-ELEMENT COMPUTER PROGRAM FOR AXISYMMETRIC LOADING SITUATIONS WHERE COMPONENTS MAY HAVE A RELATIVE INTERFERENCE FIT**

Christopher M. Taylor (Leeds Univ., England) Washington May 1977 50 p refs (NASA-TN-D-8483, E-9018) Avail NTIS HC A03/MF A01 CSCL 20K

A finite element computer program which enables the analysis of distortions and stresses occurring in compounds having a relative interference is presented. The program is limited to situations in which the loading is axisymmetric. Loads arising from the interference fit(s) and external, inertial and thermal loadings are accommodated. The components comprise several different homogeneous isotropic materials whose properties may be a function of temperature. An example illustrating the data input and program output is given. Author

**N77-23495\*** National Aeronautics and Space Administration  
Lewis Research Center, Cleveland, Ohio

**LIFE ANALYSIS OF RESTORED AND REFURBISHED BEARINGS**

John J. Coy, Erwin W. Zaretsky, and Glen R. Cowgill Washington May 1977 19 p refs Prepared in cooperation with Army Air Mobility Res. and Devel. Lab., Cleveland (NASA-TN-D-8486, E-8913) Avail NTIS HC A02/MF A01 CSCL 13I

An analysis of the potential life of refurbished and restored bearings was performed. The sensitivity of 10-percent life and mean-time-between-failure to the effects of cumulative fatigue damage and the amount of stressed volume removed in the restoration process were examined. A modified Lundberg-Palmgren theory was used to predict that the expected 10-percent life of a restored bearing, which is dependent on the previous service time and the volume of material removed from the race surfaces, can be between 74 and 100 percent of the new bearing life. Using renewal theory, it is found that the mean time between failure ranged from 90 to 100 percent of that for a new bearing. Author

**N77-24494\*** National Aeronautics and Space Administration  
Lewis Research Center, Cleveland, Ohio

**FRETTING OF AISI 9310 AND SELECTED FRETTING RESISTANT SURFACE TREATMENTS**

R. C. Bill 1977 24 p refs Presented at Ann. Meeting of the Am. Soc. of Lubrication Engineers, Montreal, Canada, 3-5 May 1977

(NASA-TM-X-73591, E-9069) Avail NTIS HC A02/MF A01 CSCL 11D

Fretting wear experiments were conducted with uncoated AISI 9310 mating surfaces, and with combinations incorporating a selected coating to one of the mating surfaces. Wear measurements and SEM observations indicated that surface fatigue, as made evident by spallation and surface crack formation, is an important mechanism in promoting fretting wear to uncoated 9310. Increasing humidity resulted in accelerated fretting, and a very noticeable difference in nature of the fretting debris. Of the coatings evaluated, aluminum bronze with a polyester additive was most effective at reducing wear and minimizing fretting damage to the mating uncoated surface, by means of a self-lubricating film that developed on the fretting surfaces. Chromium plate performed as an effective protective coating, itself resisting fretting and not accelerating damage to the uncoated surface. Author

**N77-24496\*** National Aeronautics and Space Administration  
Lewis Research Center, Cleveland, Ohio

**A CANTILEVER MOUNTED RESILIENT PAD GAS BEARING Patent Application**

Izhak Etzion, inventor (to NASA) (NAS-NRC) Filed 28 Apr 1977 12 p (NASA-Case-LEW-12569-1, US Patent Appl-SN-792069) Avail NTIS HC A02/MF A01 CSCL 13I

A gas-lubricated bearing employing at least one pad mounted on a rectangular cantilever beam to produce a lubricating wedge between the face of the pad and a moving surface is described. The load-carrying and stiffness characteristics of the pad are related to the dimensions and modulus of elasticity of the beam. The invention is applicable to a wide variety of types of hydrodynamic bearings. NASA

**N77-24498\*** National Aeronautics and Space Administration  
Lewis Research Center, Cleveland, Ohio

**GAS PATH SEAL Patent Application**

Robert C. Bill and Lawrence P. Ludwig, inventors (to NASA) Filed 27 May 1977 10 p (NASA-Case-LEW-12131-1, US Patent Appl-SN-801290) Avail NTIS HC A02/MF A01 CSCL 11A

A gas path seal suitable for use with a turbine engine or compressor is provided. A shroud wearable or abradable by the abrasion of the rotor blades of the turbine or compressor shrouds the rotor blades. A compliant backing surrounds the shroud.

The backing may be made of corrugated sheets or the like with adjacent layers having off-set corrugations, with axes of the folds parallel to the rotor axis. The sheets may be bonded together at points of contact by brazing, welding, or the like. In another embodiment a compliant material is covered with a thin ductile layer. A mounting fixture surrounds the backing. NASA

**N77-24498\*** National Aeronautics and Space Administration, Lewis Research Center, Cleveland, Ohio.

**FRICITION AND WEAR PROPERTIES OF THREE HARD REFRACTORY COATINGS APPLIED BY RADIOFREQUENCY SPUTTERING**

William A. Brainard Washington May 1977 21 p refs (NASA-TN-D-8484; E-9055) Avail: NTIS HC A02/MF A01 CSCL 11D

The adherence, friction, and wear properties of thin hard refractory compound coatings applied to 440C bearing steel by radiofrequency sputtering were investigated. Friction and wear tests were done with nonconforming pin on disk specimens. The compounds examined were chromium carbide, molybdenum silicide, and titanium carbide. The adherence, friction, and wear were markedly improved by the application of a bias voltage to the bearing steel substrate during coating deposition. Analysis by X-ray photoelectron spectroscopy indicated that the improvement may be due to a reduction in impurities in bias deposited coatings. A fivefold reduction in oxygen concentration in MoSi<sub>2</sub> coating by biasing was noted. Chromium carbide was not effective as an antiwear coating. Molybdenum silicide provided some reduction in both friction and wear. Titanium carbide exhibited excellent friction and antiwear properties at light loads. Plastic flow and transfer of the coating material onto the pin specimen appears to be important in achieving low friction and wear.

Author

**N77-25537\*** National Aeronautics and Space Administration, Lewis Research Center, Cleveland, Ohio.

**ELASTIC DISTORTION OF FLANGED INNER RING OF HIGH-SPEED CYLINDRICAL ROLLER BEARING**

Christopher M. Taylor (Leeds Univ.) Washington Jun 1977 18 p refs (NASA-TN-D-8504; E-9054) Avail: NTIS HC A02/MF A01 CSCL 131

The elastic distortion of the inner ring of an experimental roller bearing is investigated analytically. The geometry of the experimental bearing is unusually complex, and for this reason a bearing with an axially symmetric inner ring is also analyzed. Only the inner ring and shaft are considered using a two dimensional finite element program that can accommodate interference between these components. The results suggest that the elastic distortions are modest in relation to the design clearances associated with the experimental bearing. The variation of the radial deflection of the raceway may, however, be significant in some circumstances.

Author

**N77-27404\*** National Aeronautics and Space Administration, Lewis Research Center, Cleveland, Ohio.

**SHAFT SEAL ASSEMBLY FOR HIGH SPEED AND HIGH PRESSURE APPLICATIONS Patent Application**

William F. Hady and Lawrence P. Ludwig, inventors (to NASA) Filed 8 Jul. 1977 17 p (NASA-Case-LEW-11873-1; US-Patent-Appl-SN-814006) Avail: NTIS HC A02/MF A01 CSCL 13E

A seal assembly is provided for reducing the escape of fluids from between a housing and a shaft rotatably mounted in the housing. The seal assembly comprises a pair of metallic banded carbon graphite seal rings resiliently connected to each other and disposed in side-by-side relationship. In each seal ring, both the internal bore surface and the radial face which faces away from the other seal ring are provided with a plurality of equi-spaced recesses known as Raleigh step pads. The seal faces referred to are located adjacent a seating surface of the housing. Under normal operating conditions, the seal assembly is stationary with respect to the housing. The recesses generate lift, keep the assembly spaced from the rotating shaft, and allow slip therebetween. NASA

**N77-27406\*** National Aeronautics and Space Administration, Lewis Research Center, Cleveland, Ohio.

**DESIGN CHARTS FOR ARBITRARILY PIVOTED, LIQUID-LUBRICATED FLAT-SECTOR-PAD THRUST BEARING**

Izhak Etsion Jul. 1977 60 p refs (NASA-TN-D-8344; E-8899) Avail: NTIS HC A04/MF A01 CSCL 131

A flat, sector-shaped geometry for a liquid-lubricated thrust bearing is analyzed considering both the pitch and roll of the pad. Results are presented in design charts that enable a direct approach to the design of point- and line-pivoted, tilting pad bearings. A comparison is made with the Mitchell bearing approximation and it is found that this approximation always overestimates load capacity. Author

**N77-28486\*** National Aeronautics and Space Administration, Lewis Research Center, Cleveland, Ohio.

**HYDROSTATIC BEARING SUPPORT Patent**

Robert E. Cunningham, inventor (to NASA) Issued 12 Jul. 1977 4 p Filed 2 Mar. 1976 Supersedes N76-19440 (14 - 10, p 1257)

(NASA-Case-LEW-11158-1; US-Patent-4,035,037; US-Patent-Appl-SN-663008; US-Patent-Class-308-5R; US-Patent-Class-308-9; US-Patent-Class-308-73) Avail: US Patent Office CSCL 131

A hydrostatic bearing support system is provided which comprises a bearing housing having a polygonally configured outer surface which defines at least three symmetrically disposed working faces and a plurality of pressure plates, each of which is disposed relatively opposite a corresponding working face and spaced therefrom to define a gap therebetween. A hydrostatic support film is created in the gap for supporting the housing in spaced relationship to the pressure plates.

Official Gazette of the U.S. Patent Office

**N77-28493\*** National Aeronautics and Space Administration, Lewis Research Center, Cleveland, Ohio.

**HIGH-PRESSURE CRYOGENIC SEALS FOR PRESSURE VESSELS**

Alvin E. Buggele Jul. 1977 16 p refs Presented at the 6th Intern. High Pressure Conf., Boulder, Colo., 25-29 Jul. 1977; cosponsored by the Assoc. Intern. for Res. and Advan. of High Pressure Sci. and Technol. and the Intern. Union of Pure and Appl. Chem.

(NASA-TM-X-73680; E-9212) Avail: NTIS HC A02/MF A01 CSCL 11A

This investigation of the problems associated with reliably containing gaseous helium pressurized to 1530 bars (22 500 psi) between 4.2 K and 150 K led to the following conclusions: (1) common seal designs used in existing elevated-temperature pressure vessels are unsuitable for high-pressure cryogenic operation; (2) extrusion seal-ring materials such as Teflon, tin, and lead are not good seal materials for cryogenic high-pressure operation; and (3) several high-pressure cryogenic seal systems suitable for large-pressure vessel applications were developed: two seals required prepressurization, and one seal functioned repeatedly without any prepressurization. These designs used indium seal rings, brass or 304 stainless-steel anvil rings, and two O-rings of silicone rubber or Kel-F. Author

**N77-29521\*** National Aeronautics and Space Administration, Lewis Research Center, Cleveland, Ohio.

**ELASTOHYDRODYNAMIC LUBRICATION OF ELLIPTICAL CONTACTS FOR MATERIALS OF LOW ELASTIC MODULUS. 1: FULLY FLOODED CONJUNCTION**

Bernard J. Hamrock and Duncan Dowson (Leeds Univ., Engl.) Washington Aug. 1977 31 p refs (NASA-TN-D-8528; E-9216) Avail: NTIS HC A03/MF A01 CSCL 11H

Elastohydrodynamic lubrication concepts of conjunctions of elliptical form are applied to materials of low elastic modulus. The influence of the ellipticity parameter and the dimensionless speed, load, and material parameters on minimum film thickness for these materials has been investigated. The ellipticity parameter

was varied from a ball on plate configuration to a configuration approaching a line contact. The dimensionless speed and load parameters were varied by 1 order of magnitude. Seventeen different cases were used to generate minimum and central film thickness relations. Contour plots are presented that illustrate the pressure distribution and film thickness in the conjunction. Author

**N77-31502\*** National Aeronautics and Space Administration, Lewis Research Center, Cleveland, Ohio.  
**EXPERIMENTAL EVALUATION OF FOIL-SUPPORTED RESILIENT-PAD GAS-LUBRICATED THRUST BEARING**  
Zoltan N. Nemeth Sep. 1977 20 p refs  
(NASA-TP-1030: E-9061) Avail: NTIS HC A02/MF A01 CSCL 131

A new type of resilient-pad gas thrust bearing was tested to determine the feasibility of the design. The bearing consists of carbon graphite pads mounted asymmetrically on foil beams. Two bearing configurations were tested at thrust loads from 27 to 80 newtons at speeds to 9000 rpm. The outside diameter of the bearing was 8.9 centimeters. Author

**N77-32500\*** National Aeronautics and Space Administration, Lewis Research Center, Cleveland, Ohio.  
**DEFORMABLE BEARING SEAT Patent**  
Otis S. Moreman, III, inventor (to NASA) (GE, Cincinnati) Issued 6 Sep. 1977 6 p Filed 14 Jul. 1975 Sponsored by NASA  
(NASA-Case-LEW-12527-1; US-Patent-4,046,434;  
US-Patent-App'l-SN-595747; US-Patent-Class-308-195;  
US-Patent-Class-308-72; US-Patent-Class-290-52) Avail: US Patent Office, (CSCL 131)

A deformable bearing seat is described for seating a bearing assembly in a housing. The seat includes a seating surface in the housing having a first predetermined spheroidal contour when the housing is in an undeformed mode. The seating surface is deformable to a second predetermined spherically contoured surface when the housing is in a deformed mode. The seat is particularly adaptable for application to a rotating blade and mounting ring assembly in a gas turbine engine.

Official Gazette of the U.S. Patent Office

**N77-32501\*** National Aeronautics and Space Administration, Lewis Research Center, Cleveland, Ohio.  
**BEARING SEAT USABLE IN A GAS TURBINE ENGINE Patent**  
Otis S. Moreman, III, inventor (to NASA) (GE, Cincinnati) Issued 6 Sep. 1977 6 p Filed 14 Jul. 1975 Sponsored by NASA  
(NASA-Case-LEW-12477-1; US-Patent-4,046,435;  
US-Patent-App'l-SN-595745; US-Patent-Class-308-195;  
US-Patent-Class-290-52) Avail: US Patent Office CSCL 131

A blade and mounting ring assembly is described which is adapted for rotation about a first axis including a series of blades mounted on said ring for rotation about a second axis and a series of bearing assemblies, each associated with one of said blades, an improved bearing seat is provided for seating the bearing assemblies. Official Gazette of the U.S. Patent Office

**N77-32503\*** National Aeronautics and Space Administration, Lewis Research Center, Cleveland, Ohio.  
**EXPERIMENTAL AND ANALYTICAL LOAD-LIFE RELATION FOR AISI 9310 STEEL SPUR GEARS**  
D. P. Townsend, J. J. Coy, and E. V. Zaritsky Sep. 1977 27 p refs Presented at the 1977 Intern. Gear Conf., Chicago, 28-30 Sep. 1977, sponsored by ASME  
(NASA-TM-X-73590) Avail: NTIS HC A03/MF A01 CSCL 131

Life tests were conducted at three different loads with three groups of 8.9 cm pitch diameter spur gears made of vacuum arc remelted VAR AISI 9310 steel. Life was found to vary inversely with load to the 4.3 and 5.1 power at the L10 and L50 sub life levels, respectively. The Weibull slope varied linearly

with maximum Hertz contact stress, having an average value of 2.5. The test data when compared to AGMA standards showed a steeper slope for the load-life diagram. Author

**N77-32504\*** National Aeronautics and Space Administration, Lewis Research Center, Cleveland, Ohio.  
**STUDY OF LUBRICANT JET FLOW PHENOMENA IN SPUR GEARS: OUT OF MESH CONDITION**  
D. P. Townsend and L. S. Akin (Western Gear Corp., Lynnwood, Calif.) Sep. 1977 28 p refs Presented at 1977 Intern. Gear Conf., Chicago, 28-30 Sep. 1977; sponsored by ASME  
(NASA-TM-73694: E-9230) Avail: NTIS HC A03/MF A01 CSCL 131

Oil jet lubrication on the disengaging side of a gear mesh was analyzed. Results of the analysis were computerized and used to determine the oil jet impingement depth for several gear ratios and oil jet to pitch line velocity ratios. A gear test rig using high speed photography was used to experimentally determine the oil jet impingement depth on the disengaging side of mesh. Impingement depth reached a maximum at gear ratio near 1.5 where chopping by the leading gear tooth limited impingement depth. The pinion impingement depth is zero above a gear ratio of 1.172 for a jet velocity to pitch time velocity ratio of 1.0 and is similar for other velocity ratios. The impingement depth for gear and pinion are equal and approximately one half the maximum at a gear ratio of 7.0. Author

**N77-32506\*** National Aeronautics and Space Administration, Lewis Research Center, Cleveland, Ohio.  
**EFFECT OF WALL THICKNESS AND MATERIAL ON FLEXURAL FATIGUE OF HOLLOW ROLLING ELEMENTS**  
E. N. Bamberger and R. J. Parker Oct. 1977 30 p refs Presented at Joint Lubrication Conf., Kansas City, Mo., 3-5 Oct. 1977; sponsored by Am. Soc. of Lubrication Engineers and ASME  
(NASA-TM-X-73685: E-8621) Avail: NTIS CSCL 131

Hollow cylindrical bars were tested in a rolling contact fatigue tester to determine the effects of material and outside diameter to inside diameter (OD/ID) ratios on fatigue failure modes and subsequent failure propagation. The range of applied loads with OD/ID ratios of 2.0, 1.6, 1.4, and 1.2 resulted in maximum tangential tensile stresses ranging from 24,000 to 95,000 psi at the bore surface. Flexural failures of the hollow test bars occurred when this bore stress was 71,000 psi or greater with AISI 52100 hollow bars and 49,000 psi or greater with AISI M-50 hollow bars. Good correlation was obtained in relating the failures of these hollow bars with flexural failures of drilled balls from full scale bearing tests. Author

**N77-32520\*** National Aeronautics and Space Administration, Lewis Research Center, Cleveland, Ohio.  
**EFFECT OF DOUBLE VACUUM MELTING AND RETAINED AUSTENITE ON ROLLING-ELEMENT FATIGUE LIFE OF AMS 5749 BEARING STEEL**  
Richard J. Parker and Robert S. Hodder (Larrobe Steel Co., Larrobe, Pa.) Oct. 1977 16 p refs  
(NASA-TP-1060: E-9101) Avail: NTIS HC A02/MF A01 CSCL 11F

AMS 5749 steel combines the tempering, hot hardness, and hardness retention characteristics of AISI M-50 steel with the corrosion and oxidation resistance of AISI 440C stainless steel. The five-ball fatigue tester was used to evaluate the rolling-element fatigue life of AMS 5749. Double vacuum melting (vacuum induction melting plus vacuum arc remelting, VIM-VAR) produced AMS 5749 material with a rolling-element fatigue life at least 14 times that of vacuum induction melting alone. The VIM-VAR AMS 5749 steel balls gave lives from 6 to 12 times greater than VIM-VAR AISI M-50 steel balls. The highest level of retained austenite, 14.6 percent, was significantly detrimental to rolling-element fatigue life relative to the intermediate level of 11.1 percent. Author

**A77-11196 \*** Dynamics of solid lubrication as observed by optical microscopy. H. E. Sliney (NASA, Lewis Research Center, Cleveland, Ohio). *American Society of Lubrication Engineers and American Society of Mechanical Engineers, Lubrication Conference, Boston, Mass., Oct. 5-7, 1976, ASLE Preprint 76-LC-1B-4*. 8 p. 7 refs.

A bench metallograph was converted into a 'micro contact imager' by the addition of a tribometer employing a steel ball in sliding contact with a glass disk. The sliding contact was viewed in real time by means of projection microscope optics. The dynamics of abrasive particles and of solid lubricant particles within the contact were observed in detail. The contact was characterized by a constantly changing pattern of elastic strain with the passage of surface discontinuities and solid particles. Abrasive particles fragmented upon entering the contact, embedded in one surface and scratched the other; in contrast, the solid lubricant particles flowed plastically into thin films. The rheological behavior of the lubricating solids gave every appearance of a paste-like consistency within the Hertzian contact.

(Author)

**A77-11197 \*** Influence of debris dent on EHD lubrication. L. D. Wedeven (NASA, Lewis Research Center, Cleveland, Ohio). *American Society of Lubrication Engineers and American Society of Mechanical Engineers, Lubrication Conference, Boston, Mass., Oct. 5-7, 1976, ASLE Preprint 76-LC-1A-3*. 10 p. 23 refs.

Film thickness measurements associated with a debris dent have been made with interferometry under static and dynamic conditions. The presence of a debris dent alters the shape of the inlet region so that the local film thickness at the leading edge of the dent can become substantially lower than the trailing edge. The pressure modifications associated with these local EHD effects are in line with the frequent occurrence of surface initiated fatigue spalls originating at the trailing edge of debris dents. The effectiveness of the EHD mechanism in reducing the stress concentrations at the shoulders of the dent is related to inlet dimensions and dent size.

(Author)

**A77-17599 \*** Industrialization of the ion plating process. T. Spalvins (NASA, Lewis Research Center, Cleveland, Ohio). *Research /Development*, vol. 27, Oct. 1976, p. 46, 47, 48.

A new process referred to as ion plating by induction heating (IPIH) is described, which combines the advantages of both ion plating and induction heating. The IPIH apparatus consists of the specimen (cathode) to be coated and the evaporation heating source, which is a ceramic crucible containing the metal to be heated. The specimen is an internal part of the high-voltage ceramic-metal vacuum feedthrough and is connected to the negative terminal of the high-voltage power supply, the positive terminal of the power supply being grounded. The plating conditions are the same as those most commonly used in industrial ion plating. A number of metals - such as nickel, iron, platinum - which were practically impossible to deposit by resistance heating evaporation can now be effectively

evaporated and deposited to any desired thickness. Excellent adherence is observed for many metals deposited on various metal surfaces in thicknesses from 0.15 to 50 microns, regardless of the materials selected for coating and substrate.

S.D.

**A77-22983 \*** Ion beam texturing. W. R. Hudson (NASA, Lewis Research Center, Cleveland, Ohio). *(American Vacuum Society, National Vacuum Symposium, 23rd, Chicago, Ill., Sept. 21-24, 1976.) Journal of Vacuum Science and Technology*, vol. 14, Jan.-Feb. 1977, p. 286-289. 6 refs.

A microscopic surface texture was created by sputter-etching a surface while simultaneously sputter-depositing a lower sputter yield material onto the surface. A xenon ion-beam source was used to perform the texturing process on samples as large as 3-cm diameter. Textured surfaces have been characterized with SEM photomicrographs for a large number of materials including Cu, Al, Si, Ti, Ni, Fe, stainless steel, Au, and Ag. A number of texturing parameters are

studied including the variation of texture with ion-beam powder, surface temperature, and the rate of texture growth with sputter etching time.

B.J.

**A77-23478 \*** An accurate solution of the gas lubricated, flat sector thrust bearing. I. Etsion (NASA, Lewis Research Center, Cleveland, Ohio; Technion - Israel Institute of Technology, Haifa, Israel) and D. P. Fleming (NASA, Lewis Research Center, Cleveland, Ohio). *American Society of Mechanical Engineers, Joint Lubrication Conference, Boston, Mass., Oct. 5-7, 1976, Paper 76-Lub-9*. 7 p. 9 refs. Members, \$1.50; nonmembers, \$3.00.

A flat sector shaped pad geometry for gas lubricated thrust bearings is analyzed considering both pitch and roll angles of the pad and the true film thickness distribution. Maximum load capacity is achieved when the pad is tilted so as to create a uniform minimum film thickness along the pad trailing edge. Performance characteristics for various geometries and operating conditions of gas thrust bearings are presented in the form of design curves. A comparison is made with the rectangular slider approximation. It is found that this approximation is unsafe for practical design, since it always overestimates load capacity.

(Author)

**A77-23479 \*** The dual action gas thrust bearing - A new high load bearing concept. I. Etsion (NASA, Lewis Research Center, Cleveland, Ohio; Technion - Israel Institute of Technology, Haifa, Israel). *American Society of Mechanical Engineers, Joint Lubrication Conference, Boston, Mass., Oct. 5-7, 1976, Paper 76-Lub-11*. 6 p. Members, \$1.50; nonmembers, \$3.00.

The principle of utilizing hydrodynamic effects in diverging films for improving load capacity in gas thrust bearings is discussed. A new concept of dual action bearing based on that principle is described and analyzed. The potential of the new bearing is demonstrated both analytically for an infinitely long slider and by numerical solution for a flat sector shaped thrust bearing. It is shown that the dual action bearing can extend substantially the range of load-carrying capacity in gas lubricated thrust bearings and improve their efficiency.

(Author)

**A77-23482 \*** Performance of 75-millimeter bore arched outer-race ball bearings. H. H. Coe and B. J. Hamrock (NASA, Lewis Research Center, Cleveland, Ohio). *American Society of Mechanical Engineers, Joint Lubrication Conference, Boston, Mass., Oct. 5-7, 1976, Paper 76-Lub-18*. 7 p. Members, \$1.50; nonmembers, \$3.00.

An investigation was performed to determine the operating characteristics of 75-mm bore, arched outer-race bearings, and to compare the data with those for a similar, but conventional, deep groove ball bearing. Further, results of an analytical study, made using a computer program developed previously, were compared with the experimental data. Bearings were tested up to 28,000 rpm shaft speed with a load of 2,200 N (500 lb). The amount of arching was 0.13, 0.25, and 0.51 mm (0.005, 0.010, and 0.020 in). All bearings operated satisfactorily. The outer-race temperatures and the torques, however, were consistently higher for the arched bearings than for the conventional bearings.

(Author)

**A77-23492 \*** Isothermal elastohydrodynamic lubrication of point contacts. III - Fully flooded results. B. J. Hamrock (NASA, Lewis Research Center, Cleveland, Ohio) and D. Dowson (Leeds University, Leeds, England). *American Society of Mechanical Engineers, Joint Lubrication Conference, Boston, Mass., Oct. 5-7, 1976, Paper 76-Lub-30*. 12 p. 9 refs. Members, \$1.50; nonmembers, \$3.00.

Procedures outlined by the authors in an earlier publication (1976) on theoretical formulation for isothermal elastohydrodynamic lubrication of point contacts are used to assess the influence of the ellipticity parameter and the dimensionless speed, load, and material parameters on minimum film thickness. Conditions equivalent to using solid materials of bronze, steel, and silicon nitride, and



lubricants of paraffinic and naphthenic mineral oils are considered in obtaining the exponent on the dimensionless material parameter. Thirty-four different cases are used to generate the fully flooded film thickness formula. A fully flooded condition is said to exist when the inlet distance of the conjunction ceases to influence in any significant way the minimum film thickness. Contour plots are also shown that indicate in detail the pressure spike and two side lobes in which the minimum film thickness occurs. S.D.

**A77-23493 \*** # Isothermal elastohydrodynamic lubrication of point contacts. IV - Starvation results. B. J. Hamrock (NASA, Lewis Research Center, Cleveland, Ohio) and D. Dowson (Leeds, University, Leeds, England). *American Society of Mechanical Engineers, Joint Lubrication Conference, Boston, Mass., Oct. 5-7, 1976, Paper 76-Lub-31.9 p. 9 refs. Members, \$1.50; nonmembers, \$3.00.*

Previously developed basic theory for isothermal elastohydrodynamic lubrication of point contacts is used to study the effect of lubricant starvation on pressure and film thickness within the conjunction. A simple expression for the dimensionless inlet boundary distance is derived. This inlet boundary distance defines whether a fully flooded or a starved condition exists in the contact. Simple expressions for the minimum and central film thickness under starvation condition are presented. Contour plots of pressure and film thickness in and around the contact are shown in order to gain a better insight into what occurs in going from fully flooded to lubricant starvation condition. Theoretical predictions are compared with earlier results. S.D.

**A77-23495 \*** # Dynamic stiffness and damping of externally pressurized gas lubricated journal bearings. D. P. Fleming, W. J. Thayer, and R. E. Cunningham (NASA, Lewis Research Center; U.S. Army, Air Mobility Research and Development Laboratory, Cleveland, Ohio). *American Society of Mechanical Engineers, Joint Lubrication Conference, Boston, Mass., Oct. 5-7, 1976, Paper 76-Lub-33.5 p. 8 refs. Members, \$1.50; nonmembers, \$3.00.*

A rigid vertical shaft was operated with known amounts of unbalance at speeds up to 30,000 rpm and gas supply pressure ratios to 4.8. From measured amplitude and phase angle data, dynamic stiffness and damping coefficients of the bearings were determined. The measured stiffness was proportional to the supply pressure, while damping was little affected by supply pressure. Damping dropped rapidly as the fractional frequency whirl threshold was approached. A small eccentricity analysis overpredicted the stiffness by 4 to 55 percent. Predicted damping was close to measured at low speeds but higher at high speeds. (Author)

**A77-26399 \*** Sputtering. T. Spalvins (NASA, Lewis Research Center, Cleveland, Ohio). *National Bureau of Standards, Symposium of the Mechanical Failures Prevention Group, 25th, Gaithersburg, Md., Nov. 3-5, 1976, Paper, 13 p. 13 refs.*

This paper primarily reviews the potential of using the sputtering process as a deposition technique; however, the manufacturing and sputter etching aspects are also discussed. Since sputtering is not regulated by classical thermodynamics, new multicomponent materials can be developed in any possible chemical composition. The basic mechanism for dc and rf sputtering is described. Sputter-deposition is described in terms of the unique advantageous features it offers such as versatility, momentum transfer, stoichiometry, sputter-etching, target geometry (coating complex surfaces), precise controls, flexibility, ecology, and sputtering rates. Sputtered film characteristics, such as strong adherence and coherence and film morphology, are briefly evaluated in terms of varying the sputtering parameters. Also described are some of the specific industrial areas which are turning to sputter-deposition techniques. (Author)

**A77-28576 \*** # Emissions and performance of catalysts for gas turbine catalytic combustors. D. N. Anderson (NASA, Lewis Research Center, Cleveland, Ohio). *American Society of Mechanical Engineers, Gas Turbine Conference and Products Show, Philadelphia, Pa., Mar. 27-31, 1977, Paper 77-GT-65. 15 p. 15 refs. Members, \$1.50; nonmembers, \$3.00.*

Three noble-metal monolithic catalysts were tested in a 12-cm-dia. combustion test rig to obtain emissions and performance data at conditions simulating the operation of a catalytic combustor for an automotive gas turbine engine. Tests with one of the catalysts at 800 K inlet mixture temperature,  $3 \times 10$  to the 5th Pa pressure, and a reference velocity (catalyst bed inlet velocity) of 10 m/sec demonstrated greater than 99 percent combustion efficiency for reaction temperatures higher than 1300 K. With a reference velocity of 25 m/sec the reaction temperature required to achieve the same combustion-efficiency increased to 1380 K. The exit temperature pattern factors for all three catalysts were below 0.1 when adiabatic reaction temperatures were higher than 1400 K. The highest pressure drop was 4.5 percent at 25 m/sec reference velocity. Nitrogen oxides emissions were less than 0.1 g NO<sub>2</sub>/kg fuel for all test conditions. (Author)

**A77-35953 \*** Ferrographic analysis of wear debris generated in a sliding elastohydrodynamic contact. W. R. Jones, Jr. (NASA, Lewis Research Center, Cleveland, Ohio), H. S. Nagaraj, and W. O. Winer (Georgia Institute of Technology, Atlanta, Ga.). *American Society of Lubrication Engineers, Annual Meeting, 32nd, Montreal, Canada, May 9-12, 1977, Preprint 77-AM-1A-1.9 p. 11 refs.*

The Ferrograph has been used to analyze wear debris generated in a sliding elastohydrodynamic contact. The amount of wear debris correlates well with the ratio of film thickness to composite surface roughness (Lambda ratio). Essentially all of the generated wear particles were of the normal rubbing wear type. (Author)

**A77-36165 \*** # Nonlinear flap-lag axial equations of a rotating beam. K. R. V. Kaza (NASA, Langley Research Center, Aeroelasticity Branch; Hampton, Va.; NASA, Lewis Research Center, Cleveland, Ohio) and R. G. Kvaternik (NASA, Langley Research Center, Aeroelasticity Branch, Hampton Va.). *AIAA Journal*, vol. 15, June 1977, p. 871-874. 15 refs.

It is possible to identify essentially four approaches by which analysts have established either the linear or nonlinear governing equations of motion for a particular problem related to the dynamics of rotating elastic bodies. The approaches include the effective applied load artifice in combination with a variational principle and the use of Newton's second law, written as D'Alembert's principle, applied to the deformed configuration. A third approach is a variational method in which nonlinear strain-displacement relations and a first-degree displacement field are used. The method introduced by Vigneron (1975) for deriving the linear flap-lag equations of a rotating beam constitutes the fourth approach. The reported investigation shows that all four approaches make use of the geometric nonlinear theory of elasticity. An alternative method for deriving the nonlinear coupled flap-lag-axial equations of motion is also discussed. G.R.

**A77-44568 \*** # The nature of surfaces and their influence in wear mechanisms. D. H. Buckley (NASA, Lewis Research Center, Cleveland, Ohio). *Society of Automotive Engineers, International Automotive Engineering Congress and Exposition, Detroit, Mich., Feb. 28-Mar. 4, 1977, Paper, 22 p. 10 refs.*

The wear of materials is strongly dependent upon the nature of the solid surfaces in contact, their properties and the nature of the films on them. Oxide films, orientation, crystal transformations, adhesive binding, crystal structure, hardness and the presence of alloying agents are all shown to effect one or more of the forms of wear. The three most common forms of wear, adhesive, abrasive, and corrosive, are discussed in terms of the way each is affected by various material properties. Results presented indicate how wear can be optimized by concern for properties of materials. (Author)



**A77-44940 \* #** An estimation of the effect of fluid inertia on the performance of the plane inclined slider thrust bearing with particular regard to turbulent lubrication. K. F. King (Watford College of Technology, Watford, Herts., England) and C. M. Taylor (Leeds University, Leeds, England; NASA, Lewis Research Center, Cleveland, Ohio). *ASME, Transactions, Series F - Journal of Lubrication Technology*, vol. 99, Jan. 1977, p. 129-135. 25 refs.

**A77-46900 \* #** High-pressure cryogenic seals for pressure vessels. A. E. Buggle (NASA, Lewis Research Center, Cleveland, Ohio). *International Association for Research and Advancement of High Pressure Science and Technology and International Union of Pure and Applied Chemistry, International High Pressure Conference, 6th, Boulder, Colo., July 25-29, 1977, Paper*. 15 p. 8 refs.

Problems associated with maintaining high pressures at cryogenic temperatures in pressure vessels are investigated. The goals were to identify the appropriate materials and design for a seal intended for cryogenic applications at pressures up to 4,080 bars (60,000 psi), and to examine the factors affecting the seal performance. The method employed and the apparatus used in a series of experimental seal system tests, and the test results are described in detail. It is concluded that the common seal designs and extrusion seal-ring materials such as Teflon, tin, and lead are not suitable. However, new seal systems developed using indium seal rings, brass or 304 stainless steel anvil rings, and two O-rings of silicone rubber or Kel-F did prove suitable.

S.C.S.

**A77-46901 \* #** The new applications of sputtering and ion plating. T. Spalvins (NASA, Lewis Research Center, Cleveland, Ohio). *American Society of Mechanical Engineers, Design Engineering Conference and Show, Chicago, Ill., May 9-12, 1977, Paper*. 25 p. 16 refs.

The potential industrial applications of sputtering and ion plating are strictly governed by the unique features these methods possess. The outstanding features of each method, the resultant coating characteristics and the various sputtering modes and configurations are discussed. New, more complex coatings and deposits can be developed such as graded composition structures (metal-ceramic seals), laminated and dispersion strengthened composites which improve the mechanical properties and high temperature stability. Specific industrial areas where future effort of sputtering and ion plating will concentrate to develop intricate alloy or compound coatings and solve difficult problem areas are discussed.

(Author)

**N77-12403\* #** Case Western Reserve Univ., Cleveland, Ohio. Mechanical Design Dept.

**ROLLER BEARING GEOMETRY DESIGN Final Report**

Michael Savage and Bruce H. W. Pinkston 5 Oct. 1976 113 p refs

(Grant NSG-3077)

(NASA-CR-135082) Avail: NTIS HC A06/MF A01 CSCL 131

A theory of kinematic stabilization of rolling cylinders is extended and applied to the design of cylindrical roller bearings. The kinematic stabilization mechanism puts a reverse skew into the rolling elements by changing the roller taper. Twelve basic bearing modification designs are identified and modeled. Four have single transverse convex curvature in their rollers while eight have rollers which have compound transverse curvature made up of a central cylindrical band surrounded by symmetric bands with slope and transverse curvature. The bearing designs are modeled for restoring torque per unit axial displacement, contact stress capacity, and contact area including dynamic loading, misalignment sensitivity and roller proportion. Design programs are available which size the single transverse curvature roller designs for a series of roller slopes and load separations and which design the compound roller bearings for a series of slopes and transverse radii of curvature. The compound rollers are proportioned to have equal contact stresses and minimum size. Design examples are also given.

Author

**N77-23488\* #** Rocketdyne, Canoga Park, Calif.  
**SMALL, HIGH-PRESSURE LIQUID HYDROGEN TURBOPUMP Final Report, Aug. 1973 - Apr. 1976**  
A. Csomor and R. Sutton 18 May 1977 278 p refs  
(Contract NAS3-17794)  
(NASA-CR-135186; R76-115) Avail: NTIS HC A13/MF A01 CSCL 131

A high pressure, liquid hydrogen turbopump was designed, fabricated, and tested to a maximum speed of 9739 rad/s and a maximum pump discharge pressure of 2861 N/sq. cm. The approaches used in the analysis and design of the turbopump are described, and fabrication methods are discussed. Data obtained from gas generator tests, turbine performance calibration, and turbopump testing are presented.

Author

**N77-23493\* #** Boeing Commercial Airplane Co., Seattle, Wash.  
**TESTING OF POLYIMIDE SECOND-STAGE ROD SEALS FOR SINGLE-STATE APPLICATIONS IN ADVANCED AIRCRAFT HYDRAULIC SYSTEMS Final Report, Jul. 1976 - May 1977**

A. W. Waterman May 1977 57 p refs

(Contract NAS3-18529)

(NASA-CR-135191) D6-444901

Avail:

NTIS

HC A04/MF A01 CSCL 11A

Machined polyimide second-stage rod seals were evaluated to determine their suitability for single-stage applications where full system pressure acts on the upstream side of the seal. The 6.35-cm (2.5-in.) K-section seal was tested in impulse screening tests where peak pressure was increased in 3.448-MPa (500-psi) increments each 20,000 cycles. Seal failure occurred at 37.92 MPa (5,500 psi), indicating a potential for acceptability in a 27.58-MPa (4,000-psi) system. Static pressurization for 600 sec at pressures in excess of 10.34 MPa (1,500 psi) revealed structural inadequacy of the seal cross section to resist fracture and extrusion. Endurance testing showed the seals capable of at least 65,000 1.27-cm (0.5-in.) cycles at 450 K (350 F) without leakage. It was concluded that the second-stage seals were proven to be exceptional in the 1,379-MPa (200-psi) applications for which they were designed, but polyimide material properties are not adequate for use in this design at pressure loading equivalent to that present in single-stage applications.

Author

**N77-25534\* #** Pratt and Whitney Aircraft, East Hartford, Conn. Commercial Products Div.

**DEVELOPMENT OF A PLASMA SPRAYED CERAMIC GAS PATH SEAL FOR HIGH PRESSURE TURBINE APPLICATIONS Final Report, 2 Oct. 1975 - 31 Dec. 1976**

L. T. Shiembob 24 May 1977 124 p refs

(Contract NAS3-19759)

(NASA-CR-135183; PWA-5521)

Avail:

NTIS

HC A06/MF A01 CSCL 11A

The plasma sprayed graded layered yttria stabilized zirconia (ZrO<sub>2</sub>)/metal(CoCrAlY) seal system for gas turbine blade tip applications up to 1589 K (2400 F) seal temperatures was studied. Abradability, erosion, and thermal fatigue characteristics of the graded layered system were evaluated by rig tests. Satisfactory abrasability and erosion resistance was demonstrated. Encouraging thermal fatigue tolerance was shown. Initial properties for the plasma sprayed materials in the graded, layered seal system was obtained, and thermal stress analyses were performed. Sprayed residual stresses were determined. Thermal stability of the sprayed layer materials was evaluated at estimated maximum operating temperatures in each layer. Anisotropic behavior in the layer thickness direction was demonstrated by all layers. Residual stresses and thermal stability effects were not included in the analyses. Analytical results correlated reasonably well with results of the thermal fatigue tests. Analytical application of the seal system to a typical gas turbine engine application predicted performance similar to rig specimen thermal fatigue performance. A model for predicting crack propagation in the sprayed ZrO<sub>2</sub>/CoCrAlY seal system was proposed, and recommendations for improving thermal fatigue resistance were made. Seal system layer thicknesses were analytically optimized to minimize thermal stresses in the abrasability specimen during

thermal fatigue testing. Rig tests on the optimized seal configuration demonstrated some improvement in thermal fatigue characteristics. Author

**N77-27403\*** Rocketdyne, Canoga Park, Calif.  
**SMALL, HIGH-PRESSURE LIQUID OXYGEN TURBOPUMP**  
 Interim Report, Aug. 1973 - Apr. 1976  
 A. Caomor and R. Sutton Jul. 1977 289 p refs  
 (Contract NAS3-17800)  
 (NASA-CR-135211; R75-178) Avail: NTIS HC A13/MF A01 CSCL 13K

A small, high-pressure, liquid oxygen turbopump was designed, fabricated, and tested. The pump was of a single-stage, centrifugal type; power to the pump was supplied by a single-stage, partial emission, axial-impulse turbine. Design conditions included an operating speed of 70,000 rpm, pump discharge pressure of 2977 N/sq cm (4318 psia), and a pump flowrate of 16.4 kg/s (36.21 lb/sec). The turbine was propelled by LO<sub>2</sub>/LH<sub>2</sub> combustion products at 1041 K (1874 R) inlet temperature, and at a design pressure ratio of 1.424. The approaches used in the detail analysis and design of the turbopump are described, and fabrication methods are discussed. Data obtained from gas generator tests, turbine performance calibration, and turbopump testing are presented. Author

**N77-28482\*** Industrial Tectonics, Inc., Compton, Calif.  
**PERFORMANCE TESTS WITH A 4.75 INCH BORE TAPERED-ROLLER BEARINGS AT HIGH SPEEDS** Final Report  
 Hans R. Signer and Stanley I. Pinel May 1977 100 p  
 (Contract NAS3-18017)  
 (NASA-CR-135190; ITI-P-1250) Avail: NTIS HC A05/MF A01 CSCL 13I

The tapered-roller bearings were tested at speeds to 15,000 rpm which results in a cone-rib tangential velocity of 130 m/sec. (25,500 ft/min). Lubrication was applied either by jets or directly to the cone-rib, augmented with jets. Additional test parameters included thrust loads to 53,400 N (12,000 lbs), radial loads to 28,700 N (6,000 lbs), lubricant flow rates from 1.9 x 0.000 to 15.1 x 0.001 cubic meter/min. (0.5 to 4.0 gpm), and lubricant inlet temperatures of 350 K and 364 K (170 F and 195 F). Temperature distribution, separator speed, and drive-motor power demand were determined as functions of these test parameters. Author

**N77-28484\*** Carnegie-Mellon Univ., Pittsburgh, Pa.  
**SIMPLIFIED COMPUTER PROGRAM FOR THE ANALYSIS OF PHASE CHANGE IN LIQUID FACE SEALS** Final Report  
 Michael Birchak and William F. Hughes May 1977 46 p refs  
 (Grant NaG-3023)  
 (NASA-CR-134668) Avail: NTIS HC A03/MF A01 CSCL 11A

A simplified computer program is presented which allows for the prediction of boiling (phase change) in liquid face seals. The program determines if and when boiling occurs and then calculates the location of the boiling interface, pressure and temperature profiles, and load. The main assumption which allows for a simplified analysis is the assumption of an isothermal gas phase. Author

**N77-29519\*** Engelhard Minerals and Chemicals Corp., Edison, N.J.  
**DURABILITY TESTING AT ONE ATMOSPHERE OF ADVANCED CATALYSTS AND CATALYST SUPPORTS FOR AUTOMOTIVE GAS TURBINE ENGINE COMBUSTORS. PART 1** Final Report  
 R. M. Heck, M. Chang, H. Hess, and R. Carrubba Jun. 1977 231 p refs. Sponsored in part by ERDA  
 (Contract NAS3-19416)  
 (NASA-CR-135132; CONS-9416-1) Avail: NTIS HC A11/MF A01 CSCL 21B

The durability of catalysts and catalyst supports in a combustion environment was experimentally demonstrated. A test of 1000 hours duration was completed with two catalysts, using diesel fuel and operating at catalytically supported thermal combustion conditions. The performance of the catalysts was determined by monitoring emissions throughout the test, and by examining the physical condition of the catalyst core at the conclusion of the test. The test catalysts proved to be capable of low emissions operation after 1000 hours diesel aging, with no apparent physical degradation of the catalyst support. Author

**N77-31500\*** Rocketdyne, Canoga Park, Calif.  
**SMALL HIGH-SPEED SELF-ACTING SHAFT SEALS FOR LIQUID ROCKET ENGINES** Final Report, Jul. 1973 - Dec. 1976  
 R. E. Burcham and J. L. Boynton Jul. 1977 215 p refs  
 (Contract NAS3-17769)  
 (NASA-CR-135167; RI/RD77-195) Avail: NTIS HC A10/MF A01 CSCL 11A

Design analysis, fabrication, and experimental evaluation were performed on three self-acting facetype LOX seal designs and one circumferential-type helium seal design. The LOX seals featured Rayleigh step lift pad and spiral groove geometry for lift augmentation. Machined metal bellows and piston ring secondary seal designs were tested. The helium purge seal featured floating rings with Rayleigh step lift pads. The Rayleigh step pad piston ring and the spiral groove LOX seals were successfully tested for approximately 10 hours in liquid oxygen. The helium seal was successfully tested for 24 hours. The shrouded eigenvalues for each order of Bessel function  $n = 20$ , hub-to-tip ratio  $u = 0.3, 0.6$ . A computer program to obtain the three dimensional flow field in a turbomachinery with arbitrary number of blades, number of singular points per blade, and singular points locations was developed. Examples illustrating the interference effects due to hub-to-tip ratio, stagger angle, numbers of the blades were carried out. The effects of the radial variation of the strength of the radial source line were examined. The three dimensional effects are found to be appreciable for low hub tip configuration with fewer number of blades. Author (GRA)

**A77-36690\*** Fabrication of PDA/HTS prototype components, C. H. Sheppard, M. K. O'Rell, R. W. Vaughan, and R. J. Jones (TRW Systems, Redondo Beach, Calif.). In: Bicentennial of materials; Proceedings of the Eighth National Technical Conference, Seattle, Wash., October 12-14, 1976. (A77-36669 16-23) Azusa, Calif., Society for the Advancement of Material and Process Engineering, 1976, p. 257-273. Contracts No. NAS3-15834; No. NAS3-17770; No. NAS3-17824.

A process was developed for autoclave molding structural poly-(Diels-Alder) polyimide (PDA) resin/HTS graphite composites for short-term 600 F service. The autoclave molding process used to fabricate these composites required a maximum cure temperature of 427 K (400 F) and a maximum molding pressure of 0.7 MN/sq m (100 psig). This process then was adapted to the fabrication of co-cured polyimide sandwich panels consisting of PDA/HTS skins, PDA syntactic foam and polyimide/glass honeycomb core. Fabrication ease was demonstrated by manufacturing five three-quarter scale YF-12 wing panels using the PDA resin. It was concluded from successful evaluation of these prototype units that the PDA resin is suitable for fabrication of components using commercial equipment. (Author)

**A77-48714\*** Conceptual design of closed Brayton cycle for coal-fired power generation. R. P. Shah and J. C. Corman (General Electric Co., Schenectady, N.Y.). In: Intersociety Energy Conversion Engineering Conference, 12th, Washington, D.C., August 28-September 2, 1977, Proceedings. Volume 1. (A77-48701 23-44) La Grange Park, Ill., American Nuclear Society, Inc., 1977, p. 158-165. ERDA-NSF-sponsored research; Contract No. NAS3-19406.

The objectives to be realized in developing a closed cycle gas turbine are (1) to exploit high temperature gas turbine technology

while maintaining a working fluid which is free from combustion gas contamination, (2) to achieve compact turbo-equipment designs through pressurization of the working fluid, and (3) to obtain relatively simple cycle configurations. The technical/economic performance of a specific closed cycle gas turbine system was evaluated through the development of a conceptual plant and system design. This energy conversion system is designed for electric utility service and to utilize coal directly in an environmentally acceptable manner.

(Author)

## 38 QUALITY ASSURANCE AND RELIABILITY

Includes product sampling procedures and techniques; and quality control.

**N77-10557\*** National Aeronautics and Space Administration, Lewis Research Center, Cleveland, Ohio.

### MODE 1 STRESS INTENSITY FACTORS FOR ROUND COMPACT SPECIMENS

Bernard Gross 1976 7 p refs Presented at Task Group E-24.01.12 of Comm. E-24 of the Am. Soc. for Testing and Mater., Philadelphia, 5 Oct. 1976

(NASA-TM-X-73472; E-8857) Avail: NTIS HCA02/MF A01 CSDL 20K

The mode 1 stress intensity factors were computed for round compact specimens by the boundary collocation method. Results are presented for ratios  $A_{sub} T/R_{sub} O$  in the range 0.3 to 0.8, where  $A_{sub} t$  is the distance from the specimen center to the crack tip for a specimen of diameter  $2R_{sub} O$ . Author

**N77-10558\*** National Aeronautics and Space Administration, Lewis Research Center, Cleveland, Ohio.

### APPLICATION OF STRAINRANGE PARTITIONING TO THE PREDICTION OF MPC CREEP-FATIGUE DATA FOR 2 1/4 Cr-1Mo STEEL

James F. Saltsman and Gary R. Halford 1976 28 p refs Proposed for presentation at Winter Ann. Meeting of the Am. Soc. of Mechanical Engineers, New York, 5-10 Dec. 1976 (NASA-TM-X-73474) Avail: NTIS HC A03/MF A01 CSDL 13M

Strainrange partitioning is used to predict the long time cyclic lives of the metal properties council (MPC) creep-fatigue interspersed and cyclic creep-rupture tests conducted with annealed 2 1/4 Cr-1Mo steel. Observed lives agree with predicted lives within factors of two. The strainrange partitioning life relations used for the long time predictions were established from short time creep-fatigue data generated at NASA-Lewis on the same heat of material. Author

**N77-10559\*** National Aeronautics and Space Administration, Lewis Research Center, Cleveland, Ohio.

### TREATMENT OF MULTIAXIAL CREEP-FATIGUE BY STRAINRANGE PARTITIONING

S. S. Manson and G. R. Halford 1976 26 p refs Presented at the Winter Annual Meeting of the Am. Soc. of Mechanical Engineers, New York, 6-10 Dec. 1976

(NASA-TM-X-73488) Avail: NTIS HC A03/MF A01 CSDL 13M

Strainrange partitioning is a recently developed method for treating creep-fatigue interaction at elevated temperature. Most of the work to date has been on uniaxially loaded specimens, where as practical applications often involve load multiaxiality. It is shown how the method can be extended to treat multiaxiality through a set of rules for combining the strain components in the three principal directions. Closed hysteresis loops, as well as plastic and creep strain ratcheting are included. An application to hold-time tests in torsion will be used to illustrate the approach. Author

**N77-12423\*** National Aeronautics and Space Administration, Lewis Research Center, Cleveland, Ohio.

### TRAVELING-WAVE TUBE RELIABILITY ESTIMATES, LIFE TESTS, AND SPACE FLIGHT EXPERIENCE

Vincent R. Lalli and Carlton E. Speck 1977 10 p refs Proposed for Presentation at the Ann. Reliability and Maintainability Symp., Philadelphia, 17-19 Jan. 1977

(NASA-TM-X-73541; E-8973) Avail: NTIS HC A02/MF A01 CSDL 14D

Infant mortality, useful life, and wearout phase of twt life are considered. The performance of existing developmental tubes,

flight experience, and sequential hardware testing are evaluated. The reliability history of twt's in space applications is documented by considering: (1) the generic parts of the tube in light of the manner in which their design and operation affect the ultimate reliability of the device, (2) the flight experience of medium power tubes, and (3) the available life test data for existing space-qualified twt's in addition to those of high power devices.

Author

**N77-29536\*** National Aeronautics and Space Administration, Lewis Research Center, Cleveland, Ohio.

### REAL-TIME RADIOGRAPHIC INSPECTION FACILITY

Ernest Roberts, Jr. Washington Aug. 1977 21 p refs (NASA-TN-D-8529; E-9156) Avail: NTIS HC A02/MF A01 CSDL 14D

A real time radiographic inspection facility has been developed for nondestructive evaluation applications. It consists of an X-ray source, an X-ray sensitive television imaging system, an electronic analog image processing system, and a digital image processing system. The digital image processing system is composed of a computer with the necessary software to drive the overall facility. Descriptions are given of the design strategy, the facility's components, and its current capabilities. Author

**N77-33517\*** National Aeronautics and Space Administration, Lewis Research Center, Cleveland, Ohio.

### LUBRICATION OF HIGH-SPEED, LARGE BORE TAPERED-ROLLER BEARINGS

R. J. Parker and H. R. Signer (Industrial Tectonics, Inc.) 1977 29 p refs Presented at the Joint Lubrication Conf., Kansas City, 3-5 Oct. 1977; sponsored by ASLE and ASME

(NASA-TM-X-73673; E-8825) Avail: NTIS HC A03/MF A01 CSDL 111

The performance of 120.65-mm- (4.75-in.-) bore tapered-roller bearings was investigated at shaft speeds up to 15,000 rpm (18,000 DN). Temperature distribution and bearing heat generation were determined as a function of shaft speed, radial and thrust loads, lubricant flow rate, and lubricant inlet temperature. Lubricant was supplied either by jets or by a combination of holes through the cone directly to the cone-rib contact and jets at the roller small-end side. Cone-rib lubrication significantly improved high-speed tapered-roller bearing performance, yielding lower cone-face temperatures and lower power loss and allowing lower lubricant flow rates for a given speed condition. Bearing temperatures increased with increased shaft speed and decreased with increased lubricant flow rate. Bearing power loss increased with increased shaft speed and increased lubricant flow rate.

Author

**N77-33518\*** National Aeronautics and Space Administration, Lewis Research Center, Cleveland, Ohio.

### DESIGN CONSIDERATIONS IN MECHANICAL FACE SEALS FOR IMPROVED PERFORMANCE. 2: LUBRICATION

Lawrence P. Ludwig and Harold F. Greiner (Sealol, Inc.) 1977 20 p refs Presented at Winter Ann. Meeting of ASME, Atlanta, 27 Nov. - 2 Dec. 1977

(NASA-TM-73736; E-9298-2) Avail: NTIS HC A02/MF A01 CSDL 11A

The importance of sealing technology in our industrial, chemical-oriented society in regard to maintenance and environmental contamination is pointed out. It is stated that seal performance (leakage, life) is directly related to seal lubrication. Current thinking in regard to seal lubrication is reviewed; the effect of energy dissipation in the thin lubricating film separating the sealing faces is pointed out, and the results of vaporization due to heating are illustrated. Also, hydrodynamic lubrication is reviewed, and an inherent tendency for the seal to operate with angular misalignment is shown. Recent work on hydrostatic effects is summarized and the conditions for seal instability are discussed. Four different modes of seal lubrication are postulated with the mode type being a strong function of speed and pressure.

Author

N77-18477\* Westinghouse Electric Corp., Pittsburgh, Pa.  
**RADIOGRAPHIC AMPLIFIER SCREENS: FABRICATION  
PROCESS AND CHARACTERISTICS** Final Report  
Zoltan Szepesi Mar. 1977 27 p refs  
(Contract NAS3-19902)  
(NASA-CR-2822; Rept-76-9G9-RASPA-R1) Avail: NTIS  
HC A02/MF A01 CSCL 14D

The fabrication process and transfer characteristics for solid state radiographic image transducers (radiographic amplifier screens) is described. These screens were developed for use in real time nondestructive evaluation procedures that require large format radiographic images with contrast and resolution capabilities unavailable with conventional fluoroscopic screens. This work was directed toward screens usable for inmotion, on-line radiographic inspection by means of closed circuit television.

Author

## 39 STRUCTURAL MECHANICS

Includes structural element design and weight analysis; fatigue; and thermal stress.

For applications see 05 Aircraft Design, Testing and Performance and 18 Spacecraft Design, Testing and Performance.

**N77-11436\*** National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio.

### CYCLIC STRUCTURAL ANALYSIS OF AIR-COOLED GAS TURBINE BLADES AND VANES

Albert Kaufman and Raymond E. Gaupier 1976 30 p refs Presented at the Aerospace E. S. Conf., San Diego, Calif. 29 Nov. - 2 Dec. 1976 Sponsored by the Soc. of Automotive Eng.

(NASA-TM-X-73494; E-8892) Avail: NTIS HC A03/MF A01 CSDL 21E

The creep fatigue behavior of a fully impingement cooled blade for four cyclic cases was analyzed by using the Elas 55, finite element, nonlinear structural computer program. Expected cyclic lives were calculated by using the method of strainrange partitioning for reversed inelastic strains and time fractions for ratcheted tensile creep strains. Strainrange partitioning was also applied to previous results from a one dimensional cyclic analysis of a film impingement cooled vane. The analyses indicated that strainrange partitioning is more applicable to a constrained airfoil such as the film impingement cooled vane than to the relatively unconstrained fully impingement cooled airfoil. Author

**N77-11442\*** National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio.

### RIM-SPOKE COMPOSITE FLYWHEELS: STRESS AND VIBRATION ANALYSIS

Christos C. Chamis and Louis J. Kiraly Washington Nov. 1976 21 p ref Presented at 1975 Flywheel Technol. Symp., Berkeley, Calif. 10-12 Nov. 1975

(NASA-TN-D-8339; E-8657) Avail: NTIS HC A02/MF A01 CSDL 20K

Elementary relations are described to determine the material utilization efficiency of a thin wall rim composite flywheel over other configurations. An algorithm is generated for the automatic selection of the optimum composite material for a given thin rim flywheel environment. Subsequently, the computer program NASTRAN is used to perform a detailed stress and vibration analysis of thin wall cylindrical shell rim spoke, single rim and multirim composite flywheels for a specific application. Author

**N77-13457\*** National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio.

### HEAVY SECTION FRACTURE TOUGHNESS SCREENING SPECIMEN

John L. Shannon, Jr., J. Keith Donald (Ocean City Res. Corp., Hellertown, Pa.), and William F. Brown, Jr. May 1976 24 p refs Presented at the Symp. on Develop. in Fracture Mech. Test Method Standardization, St. Louis, 2-7 May 1976; sponsored by Am. Soc. Test Mater.

(NASA-TM-X-73561) Avail: NTIS HC A02/MF A01 CSDL 11F

Size requirements for a pin loaded double edge notch + crack tension specimen proposed for fracture toughness screening heavy section alloys were studied. Ranking of eight selected alloys based on the specimen's net strength was compared with that based on the valid plane strain fracture toughness separately determined. Performance of the specimen was judged on the basis of that comparison. The specimen's net strength was influenced by three critical specimen dimensions: distance between the crack plane and the loading hole, specimen width, and specimen thickness. Interaction between the stress fields of the crack and the loading holes reduced the net strength, but this effect disappeared as the separation reached a dimension equal to the specimen width. The effects of specimen width and thickness are interrelated and affect the net strength through their influence on the development of the crack tip plastic zone. Author

**N77-18441\*** National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio.

### FREE-VIBRATION CHARACTERISTICS OF A LARGE SPLIT-BLANKET SOLAR ARRAY IN A 1-g FIELD

Francis J. Shaker Washington Dec. 1976 62 p refs (NASA-TN-D-8376; E-8827) Avail: NTIS HC A04/MF A01 CSDL 13M

Two methods for studying the free vibration characteristics of a large split blanket solar array in both a 0-g and a 1-g cantilevered configuration are presented. The 0-g configuration corresponds to an in-orbit configuration of the array; the 1-g configuration is a typical ground test configuration. The first method applies the equations of continuum mechanics to determine the mode shapes and frequencies of the array; the second method uses the Rayleigh-Ritz approach. In the Rayleigh-Ritz method the array displacements are represented by string modes and cantilevered beam modes. The results of this investigation are summarized by a series of graphs illustrating the effects of various array parameters on the mode shapes and frequencies of the system. The results of the two methods are also compared in tabular form. Author

**N77-19486\*** National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio.

### LOAD-DISPLACEMENT MEASUREMENT AND WORK DETERMINATION IN THREE-POINT BEND TESTS OF NOTCHED OR PRECRACKED SPECIMENS

Robert J. Buzzard and Douglas M. Fisher 1977 16 p refs Presented at the Task Group E-2-01.09 of the Am. Soc. for Testing and Mater. Comm., Norfolk, Va. 22-25 Mar. 1977

(NASA-TM-X-73596; E-8378) Avail: NTIS HC A02/MF A01 CSDL 13M

Suggestions for testing of notched or cracked three-point bend specimens are presented which: (1) correct displacement measurement errors resulting from misalignment between the load applicator and specimen; (2) account for coincidental strains not associated with the work of crack extension; (3) simplify record analysis and processing; and (4) extend displacement gage range without sacrifice of sensitivity or accuracy. These testing details are particularly applicable to procedures in which the crack extension force is determined from the work done on the specimen. Author

**N77-20482\*** National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio.

### FATIGUE CRITERION FOR THE DESIGN OF ROTATING SHAFTS UNDER COMBINED STRESS

Stuart H. Loewenthal Mar. 1977 9 p refs (NASA-TM-X-73639; E-9141) Avail: NTIS HC A02/MF A01 CSDL 13M

A revised approach to the design of transmission shafting which considers the flexure fatigue characteristics of the shaft material under combined cyclic bending and static torsion stress is presented. A fatigue failure relation, corroborated by published combined stress test data, is presented which shows an elliptical variation of reversed bending endurance strength with static torsional stress. From this elliptical failure relations, a design formula for computing the diameter of rotating solid shafts under the most common condition of loading is developed. Author

**N77-20504\*** National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio.

### NASTRAN AS AN ANALYTICAL RESEARCH TOOL FOR COMPOSITE MECHANICS AND COMPOSITE STRUCTURES

C. C. Chamis, J. H. Sinclair, and T. L. Sullivan In its NASTRAN: User's Experiences Oct. 1976 p 381-418 refs (For primary document see N77-20485 11-39)

Avail: NTIS HC A24/MF A01 CSDL 13M

Selected examples are described in which NASTRAN is used as an analysis research tool for composite mechanics and for composite structural components. The examples were selected to illustrate the importance of using NASTRAN as an analysis tool in this rapidly advancing field. Author

**N77-27431\*** National Aeronautics and Space Administration, Lewis Research Center, Cleveland, Ohio.  
**MODE I ANALYSIS OF A CRACKED CIRCULAR DISK SUBJECT TO A COUPLE AND A FORCE**  
 Bernard Gross 1977 15 p refs  
 (NASA-TM-73692; E-9228) Avail: NTIS HC A02/MF A01 CSDL 20K

Mode I stress intensity coefficients were obtained for an edge-cracked disk (round compact specimen). Results for this plane elastostatic problem, obtained by a boundary collocation analysis are presented for ratios 0.35 less than  $A/D$  less than 1, where  $A$  is the crack length and  $D$  is the disk diameter. The results presented are for two complementary types of loading. By superposition of these results the stress intensity factor  $K$  sub I for any practical load line location of a pin-loaded round compact specimen can be obtained. Author

**N77-27437\*** National Aeronautics and Space Administration, Lewis Research Center, Cleveland, Ohio.  
**MULTIAXIAL CREEP-FATIGUE LIFE ANALYSIS USING STRAINRANGE PARTITIONING**

S. S. Manson (Case Western Reserve Univ.) and J. R. Halford Nov. 1976 51 p refs Presented at Ann. Meeting of Am. Soc. Mech. Eng., New York, Dec. 1976  
 (Contract W-7405-eng-26)

(NASA-TM-74756; Conf. 761107-3) Avail: NTIS HC A04/MF A01 CSDL 13M

The method to treat multiaxiality through a set of rules for combining the strain components in the three principal directions is presented. Closed hysteresis loops, as well as plastic and creep strain ratcheting, are included. An application to holdtime tests in torsion is used to illustrate the approach. ERA

**N77-28521\*** National Aeronautics and Space Administration, Lewis Research Center, Cleveland, Ohio.

**THREE-DIMENSIONAL ELASTIC STRESS AND DISPLACEMENT ANALYSIS OF FINITE GEOMETRY SOLIDS CONTAINING CRACKS**

Jonathan King, John Gyekenyesi, and Alexander Mendelson 1977 16 p refs Presented at 23d Conf. of Army Mathematicians, Hampton, Va., 11-13 May 1977. Sponsored by the Dept. of the Army Prepared in cooperation with Army Air Mobility R and D Lab., Cleveland, Ohio

(NASA-TM-73717; E-9263) Avail: NTIS HC A02/MF A01 CSDL 20K

The line method of analysis is applied to the Navier-Cauchy equations of elastic equilibrium to calculate the displacement fields in finite geometry bars containing central, surface, and double-edge cracks under extensionally applied uniform loading. The application of this method to these equations leads to coupled sets of simultaneous ordinary differential equations whose solutions are obtained along sets of lines in a discretized region. Normal stresses and the stress intensity factor variation along the crack periphery are calculated using the obtained displacement field. The reported results demonstrate the usefulness of this method in calculating stress intensity factors for commonly encountered crack geometries in finite solids. Author

**N77-28522\*** National Aeronautics and Space Administration, Lewis Research Center, Cleveland, Ohio

**DISPLACEMENT COEFFICIENTS ALONG THE INNER BOUNDARIES OF RADIALLY CRACKED RING SEGMENTS SUBJECT TO FORCES AND COUPLES**

Bernard Gross Jul. 1977 17 p refs  
 (NASA-TM-73730; E-9218) Avail: NTIS HC A02/MF A01 CSDL 20K

Displacement results of plane boundary collocation analysis are given for various locations on the inner boundaries of radially cracked ring segments (C-shaped specimens) subject to two complementary types of loading. Results are presented for ratios of outer to inner radius  $R$  sub o/ $R$  sub i in the range of 1.1 to 2.5, and ratios  $a/W$  in the range 0.1 to 0.8 where  $a$  is the crack length for a specimen of wall thickness  $W$ . By combination

of these results the resultant displacement coefficient delta or the corresponding influence coefficient, can be obtained for any practical load line location of a pin loaded specimen. Author

**N77-28558\*** National Aeronautics and Space Administration, Lewis Research Center, Cleveland, Ohio.

**SCANNING-ELECTRON-MICROSCOPY OBSERVATIONS AND MECHANICAL CHARACTERISTICS OF ION-BEAM-SPUTTERED SURGICAL IMPLANT ALLOYS**

Albert J. Weigand, M. Lise Meyer, and Jerri S. Ling Washington Aug. 1977 33 p refs

(NASA-TM-X-3553; E-9056) Avail: NTIS HC A03/MF A01 CSDL 11F

An electron bombardment ion thruster was used as an ion source to sputter the surfaces of orthopedic prosthetic metals. Scanning electron microscopy photomicrographs were made of each ion beam textured surface. The effect of ion texturing an implant surface on its bond to bone cement was investigated. A Co-Cr-W alloy and surgical stainless steel were used as representative hard tissue implant materials to determine effects of ion texturing on bulk mechanical properties. Work was done to determine the effect of substrate temperature on the development of an ion textured surface microstructure. Results indicate that the ultimate strength of the bulk materials is unchanged by ion texturing and that the microstructure will develop more rapidly if the substrate is heated prior to ion texturing. Author

**N77-30500\*** National Aeronautics and Space Administration, Lewis Research Center, Cleveland, Ohio.

**C-SHAPED SPECIMEN PLANE STRAIN FRACTURE TOUGHNESS TESTS**

R. T. Buzzard and D. M. Fisher Jul. 1977 20 p refs  
 (NASA-TM-73731; E-9291) Avail: NTIS HC A02/MF A01 CSDL 20K

Test equipment, procedures, and data obtained in the evaluation of C-shaped specimens are presented. Observations reported on include: specimen preparation and dimensional measurement; modifications to the standard ASTM E 399 displacement gage, which permit punch mark gage point engagement; and a measurement device for determining the interior and exterior radii of ring segments. Load displacement ratios were determined experimentally which agreed with analytically determined coefficients for three different gage lengths on the inner surfaces of radially-cracked ring segments. Author

**N77-31544\*** National Aeronautics and Space Administration, Lewis Research Center, Cleveland, Ohio.

**THE USE OF PARABOLIC VARIATIONS AND THE DIRECT DETERMINATION OF STRESS INTENSITY FACTORS USING THE BIE METHOD**

Alexander Mendelson 1977 16 p refs Presented at the Symp. on Appl. of Computer Methods Eng., Los Angeles, 23-26 Aug. 1977; sponsored by the Univ. of Southern Calif. (NASA-TM-X-73681; E-9214) Avail: NTIS HC A02/MF A01 CSDL 13M

Two advances in the numerical techniques of utilizing the BIE method are presented. The boundary unknowns are represented by parabolas over each interval which are integrated in closed form. These integrals are listed for easy use. For problems involving crack tip singularities, these singularities are included in the boundary integrals so that the stress intensity factor becomes just one more unknown in the set of boundary unknowns thus avoiding the uncertainties of plotting and extrapolating techniques. The method is applied to the problems of a notched beam in tension and bending, with excellent results. Author

**N77-33536\*** National Aeronautics and Space Administration, Lewis Research Center, Cleveland, Ohio.

**DUCTILITY NORMALIZED-STRAINRANGE PARTITIONING LIFE RELATIONS FOR CREEP-FATIGUE LIFE PREDICTIONS**

G. R. Malford, J. F. Saltsman, and M. H. Hirschberg 1977 17 p refs Presented at Conf. on Environ. Effects and Degradation of Eng. Mater., Blacksburg, Va., 10-12 Oct. 1977; sponsored by Va. Polytech. Inst.

(NASA-TM-73737) Avail: NTIS HC A02/MF A01 CSCL 20K Procedures based on Strainrange Partitioning (SRP) are presented for estimating the effects of environment and other influences on the high temperature, low cycle, creep, fatigue resistance of alloys. It is proposed that the plastic and creep ductilities determined from conventional tensile and creep rupture tests conducted in the environment of interest be used in a set of ductility normalized equations for making a first order approximation of the four SRP inelastic strainrange life relations. Different levels of sophistication in the application of the procedures are presented by means of illustrative examples with several high temperature alloys. Predictions of cyclic lives generally agree with observed lives within factors of three. Author

**A77-30871 •** Doubly-curved variable-thickness isoparametric heterogeneous finite element. M. D. Minich (Cleveland State University, Cleveland, Ohio) and C. C. Chamis (NASA, Lewis Research Center, Cleveland, Ohio). (National Symposium on Computerized Structural Analysis and Design, 2nd, George Washington University, Washington, D.C., Mar. 29-31, 1976.) Computers and Structures, vol. 7, Apr. 1977, p. 295-301, 12 refs.

This paper describes an element streamlined for the analysis of doubly curved, variable-thickness structural components and illustrates its effective application to vibration and static problems. The element is isoparametric, doubly-curved, thin-shell and triangular with variable thickness and accounts for anisotropic, inhomogeneous elastic material behavior. The element has six nodes (three corner and three mid-side) with five degrees-of-freedom (DOF) per node - three translations and two rotations. Quadratic isoparametric interpolation polynomials are used to express the element geometry and displacement variables in terms of corresponding nodal variables.

(Author)

**A77-31576 • #** Concepts for the development of light-weight composite structures for rotor burst containment. A. G. Holms (NASA, Lewis Research Center, Cleveland, Ohio). NASA Workshop on an Assessment of Technology for Turbojet Engine Rotor Failures, Cambridge, Mass., Mar. 29-31, 1977, Paper. 33 p. 17 refs.

Based on published results on rotor burst containment with single materials, and on body armor using composite materials, a set of hypotheses is established as to what variables might control the design of a weight-efficient protective device. Based on modern concepts for the design and analysis of small optimum seeking experiments, a particular experiment for evaluating the hypotheses and materials was designed. The design and methods for the analysis of results are described.

(Author)

**A77-47957 • #** Three-dimensional elastic stress and displacement analysis of finite geometry solids containing cracks. J. Kring, J. Gyekenyesi, and A. Mendelson (NASA, Lewis Research Center; U.S. Army, Air Mobility Research and Development Laboratory, Cleveland, Ohio). U.S. Army, Conference of Army Mathematicians, 23rd, Hampton, Va., May 11-13, 1977, Paper. 15 p. 18 refs.

The line method of analysis is applied to the Navier-Cauchy equations of elastic equilibrium to calculate the displacement fields in finite geometry bars containing central, surface, and double-edge cracks under extensionally applied uniform loading. The application of this method to these equations leads to coupled sets of simultaneous ordinary differential equations whose solutions are obtained along sets of lines in a discretized region. Normal stresses and the stress intensity factor variation along the crack periphery are calculated using the obtained displacement field. The reported results demonstrate the usefulness of this method in calculating stress intensity factors for commonly encountered crack geometries in finite solids.

(Author)

**A77-51578 •** Developments in fracture mechanics test methods standardization; Proceedings of the Symposium, St. Louis, Mo., May 4, 1976. Symposium sponsored by the American Society for Testing and Materials and NASA. Edited by W. F. Brown, Jr. (NASA, Lewis Research Center, Cleveland, Ohio) and J. G. Kaufman (Aluminum Company of America, Alcoa Center, Pa.). Philadelphia, Pa., American Society for Testing and Materials (ASTM Special Technical Publication, No. 632), 1977. 293 p. Members, \$14.80; nonmembers, \$24.75. (For individual items see A77-51577 to A77-51585)

Experience in plane-strain fracture toughness testing per ASTM Method E 399 is considered along with fracture toughness testing using the C-shaped specimen, an analysis of radially cracked ring segments subject to forces and couples, compliance calibration of specimens used in the R-curve practice, heavy-section fracture toughness screening specimen, and sharply notched cylindrical tension specimens for screening plane-strain fracture toughness. Attention is also given to an investigation of some problems in developing standards for precracked Charpy specimen strength ratios, fracture testing with surface crack specimens, and the estimation of plane strain fracture toughness values from slow bend precracked Charpy specimen strength ratios.

G.R.

**A77-51578 • #** Analysis of radially cracked ring segments subject to forces and couples. B. Gross and J. E. Srawley (NASA, Lewis Research Center, Fracture Mechanics Section, Cleveland, Ohio). In: Developments in fracture mechanics test methods standardization; Proceedings of the Symposium, St. Louis, Mo., May 4, 1976. (A77-51576 24-39) Philadelphia, Pa., American Society for Testing and Materials, 1977, p. 39-56, 8 refs.

Results of planar boundary collocation analysis are given for ring segment (C-shaped) specimens with radial cracks, subjected to combined forces and couples. Mode I stress intensity factors and crack mouth opening displacements were determined for ratios of outer to inner radius in the range 1.1 to 2.5 and ratios of crack length to segment width in the range 0.1 to 0.8.

(Author)

**A77-51582 • #** Heavy-section fracture toughness screening specimen. J. L. Shannon, Jr., W. F. Brown, Jr. (NASA, Lewis Research Center, Cleveland, Ohio), and J. K. Donald (Ocean City Research Corp., Hellertown, Pa.). In: Developments in fracture mechanics test methods standardization; Proceedings of the Symposium, St. Louis, Mo., May 4, 1976. (A77-51576 24-39) Philadelphia, Pa., American Society for Testing and Materials, 1977, p. 96-114, 6 refs.

The reported study has the objective to fix the proportions and limits of application of a double-edge-notch specimen with one of the notches tipped with a fatigue crack (DENC). Details regarding the DENC specimen are discussed, taking into account specimen length, notch length, specimen width and thickness, and the loading pins. The influence of specimen width and thickness on the crack strength and apparent plane-strain fracture toughness of the specimen has been determined for eight alloys. It is concluded that the DENC specimen shows promise for screening alloys with reference to their plane-strain fracture toughness in sections up to 1 in.

G.R.

**A77-51584 • #** Investigation of some problems in developing standards for precracked Charpy slow bend tests. G. Succop, R. T. Bubbey, M. H. Jones, and W. F. Brown, Jr. (NASA, Lewis Research Center, Fracture Branch, Cleveland, Ohio). In: Developments in fracture mechanics test methods standardization; Proceedings of the Symposium, St. Louis, Mo., May 4, 1976. (A77-51576 24-39) Philadelphia, Pa., American Society for Testing and Materials, 1977, p. 153-178, 13 refs.

The reported investigation was undertaken in connection with an attempt to develop procedures which would be useful in standardizing a test method for the precracked Charpy slow bend specimen. A number of alloys was studied for which valid plane-

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strain fracture toughness values have been established. The investigation shows that useful relations between precracked Charpy slow bend results and crack size factors can be obtained under some circumstances. However, it is not yet known what factors control these circumstances. G.R.

**A77-51585 \*** Estimation of  $K(Ic)$  from slow bend precracked Charpy specimen strength ratios. G. Succop and W. F. Brown, Jr. (NASA, Lewis Research Center, Fracture Branch, Cleveland, Ohio). In: Developments in fracture mechanics test methods standardization; Proceedings of the Symposium, St. Louis, Mo., May 4, 1976. (A77-51576 24-39) Philadelphia, Pa., American Society for Testing and Materials, 1977, p. 179-192. 9 refs.

Data are presented concerning strength ratios which have been derived from slow bend tests on 0.25-in.-thick precracked Charpy specimens of steels, aluminum alloys, and a titanium alloy for which valid  $K(Ic)$  values have been established. The  $K(Ic)$  values considered are plane strain fracture toughness values as defined in the ASTM Method E 399-74. The strength ratios are used to develop calibration curves which could be useful in estimating  $K(Ic)$  for the purposes of alloy development or quality control. G.R.

**N77-21467\*** Lockheed-California Co., Burbank.  
**A 100-kW METAL WIND TURBINE BLADE BASIC DATA, LOADS AND STRESS ANALYSIS Final Report**

A. W. Cherritt and J. A. Gaidelis Jun. 1975 241 p ref (Contract NAS3-19235)

(NASA-CR-134956; LR-27153) Avail: NTIS  
HC A11/MF A01 CSCL 13M

A rotor loads computer program was used to define the steady state and cyclic loads acting on 60 ft long metal blades designed for the ERDA/NASA 100 kW wind turbine. Blade load and stress analysis used to support the structural design are presented. For the loading conditions examined, the metal blades are structurally adequate for use, within the normal operating range, as part of the wind turbine system. Author

**N77-21468\*** Lockheed-California Co., Burbank.  
**A 100-kW WIND TURBINE BLADE DYNAMICS ANALYSIS, WEIGHT-BALANCE, AND STRUCTURAL TEST RESULTS Final Report**

W. D. Anderson Jun. 1975 102 p refs (Contract NAS3-19235)

(NASA-CR-134957; LR-27230) Avail: NTIS  
HC A06/MF A01 CSCL 13M

The results of dynamic analyses, weight and balance tests, static stiffness tests, and structural vibration tests on the 60-foot-long metal blades for the ERDA-NASA 100-kW wind turbine are presented. The metal blades are shown to be free from structural or dynamic resonance at the wind turbine design speed. Aeroelastic instabilities are unlikely to occur within the normal operating range of the wind turbine. Author

**N77-25576\*** Martin Marietta Corp., Denver, Colo.  
**CHARACTERIZATION OF CRACK GROWTH UNDER COMBINED LOADING Final Report. 6 Jun. 1974 - 15 Mar. 1977**

A. Feldman, F. W. Smith, and A. Holston, Jr. Jun. 1977 246 p refs

(Contract NAS3-17810)  
(NASA-CR-135197; MCR-77-131) Avail: NTIS  
HC A11/MF A01 CSCL 13M

Room-temperature static and cyclic tests were made on 21 aluminum plates in the shape of a 91.4x91.4-cm Maltese cross with 45 deg flaws to develop crack growth and fracture toughness data under mixed-mode conditions. During cyclic testing, it was impossible to maintain a high proportion of shear-mode deformation on the crack tips. Cracks either branched or turned. Under static loading, cracks remained straight if shear stress intensity exceeded normal stress intensity. Mixed-mode crack growth

rate data compared reasonably well with published single-mode data, and measured crack displacements agreed with the straight and branched crack analyses. Values of critical strain energy release rate at fracture for pure shear were approximately 50% higher than for pure normal opening, and there was a large reduction in normal stress intensity at fracture in the presence of high shear stress intensity. Net section stresses were well into the inelastic range when fracture occurred under high shear on the cracks. Author

**A77-17064 \*** Proof test criteria for thin walled pressure vessels. R. W. Finger (Boeing Aerospace Co., Seattle, Wash.). Sagamore Army Materials Research Conference, Raquette Lake, N.Y., Sept. 9, 1976, Paper. 40 p. 6 refs. Contract No. NAS3-18906.

Proof tests were conducted on surface-flaw pressure-vessel specimens of 2219-T87 aluminum base metal and weld metal at three different temperatures: 72, -320, and -423 F, and for three different metal sheet thicknesses: 0.125, 0.250, and 0.375 in. It was found that significant stable crack growth under increasing load can occur prior to failure. Initial flaw shapes and material conditions have a significant effect on the extent of crack growth. Stable crack growth initiates at a lower  $K$  sub li/ $K$  sub cr ratio and is more severe in weld metal specimens than in base metal specimens. Low aspect ratio flaws experience more growth in the depthwise direction than higher aspect ratio flaws. Proof testing assures that any first cycle failure will be by leakage, not by catastrophic failure. B.J.

**A77-29856 \*** Low-cycle fatigue analysis of the turbine disk for the National Aeronautics and Space Administration high-temperature turbine rig. S. Tepper (AiResearch Manufacturing Company of California, Torrance, Calif.). In: Thermal fatigue of materials and components; Proceedings of the Symposium, New Orleans, La., November 17, 18, 1975. (A77-29852 12-26) Philadelphia, Pa., American Society for Testing and Materials, 1976, p. 38-54, 9 refs. Contract No. NAS3-17736.

## 42 GEOSCIENCES (GENERAL)

**N77-30521\*** National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio.

### **TERRESTRIAL PHOTOVOLTAIC MEASUREMENTS. 2**

1976 393 p refs Workshop held at Baton Rouge, La., 10-12 Nov. 1976; sponsored by NASA and ERDA (NASA-CP-2010; ERDA/NASA-1022-76/10) Avail: NTIS HC A17/MF A01 CSCL 10A

The following major topics are discussed: (1) Terrestrial solar irradiance; (2) Solar simulation and reference cell calibration; and (3) Cell and array measurement procedures. Numerous related subtopics are also discussed within each major topic area. For individual titles, see N77-30522 through N77-30544.

**N77-30525\*** National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio.

### **TEST FACILITY FOR SOLAR-CELL REFERENCE CONDITIONS**

Thomas M. Klucher *In its Terrest. Photovoltaic Meas., 2* 1976 p 87-78 refs Previously announced as N77-26618 (For primary document see N77-30521 21-42)

Avail: NTIS HC A17/MF A01 CSCL 10A

For abstract, see N77-26618 on page 136.

**N77-30527\*** National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio.

### **THE EFFECT OF ATMOSPHERIC PARAMETERS ON SILICON CELL PERFORMANCE**

Henry B. Curtis *In its Terrest. Photovoltaic Meas., 2* 1976 p 93-108 refs Previously announced as N77-26619 (For primary document see N77-30521 21-42)

Avail: NTIS HC A17/MF A01 CSCL 10A

For abstract, see N77-26619 on page 136.

**N77-30529\*** National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio.

### **ERRORS IN SHORT CIRCUIT CURRENT MEASUREMENTS DUE TO SPECTRAL MISMATCH BETWEEN SUNLIGHT AND SOLAR SIMULATORS**

Henry B. Curtis *In its Terrest. Photovoltaic Meas., 2* 1976 p 161-182 ref Previously announced as N77-26620 (For primary document see N77-30521 21-42)

Avail: NTIS HC A17/MF A01 CSCL 10A

For abstract, see N77-26620 on page 136.

**N77-30531\*** National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio.

### **CONSIDERATION OF DESIGN AND CALIBRATION OF TERRESTRIAL REFERENCE SOLAR CELLS**

V. G. Weizer *In its Terrest. Photovoltaic Meas., 2* 1976 p 203-222 refs Previously announced as N77-26621 (For primary document see N77-30521 21-42)

Avail: NTIS HC A17/MF A01 CSCL 10A

For abstract, see N77-26621 on page 136.

**N77-30533\*** National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio.

### **SOME BASIC CONSIDERATIONS OF MEASUREMENTS INVOLVING COLLIMATED DIRECT SUNLIGHT**

An-Ti Chai *In its Terrest. Photovoltaic Meas., 2* 1976 p 233-246 refs Previously announced as N77-26622 (For primary document see N77-30521 21-42)

Avail: NTIS HC A17/MF A01 CSCL 03B

For abstract, see N77-26622 on page 136.

**N77-30534\*** National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio.

### **SENSITIVITY OF SOLAR CELL PERFORMANCE TO ATMOSPHERIC VARIABLES. 1: SINGLE CELL**

Thomas M. Klucher *In its Terrest. Photovoltaic Meas., 2* 1976 p 247-258 refs Previously announced as N77-26623 (For primary document see N77-30521 21-42)

Avail: NTIS HC A17/MF A01 CSCL 10A

For abstract, see N77-26623 on page 136.

**N77-30535\*** National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio.

### **SENSITIVITY OF SOLAR-CELL PERFORMANCE TO ATMOSPHERIC VARIABLES. 2: DISSIMILAR CELLS AT SEVERAL LOCATIONS**

Thomas M. Klucher and Russell E. Hart *In its Terrest. Photovoltaic Meas., 2* 1976 p 259-270 refs Previously announced as N77-26624 (For primary document see N77-30521 21-42)

Avail: NTIS HC A17/MF A01 CSCL 10A

For abstract, see N77-26624 on page 137.

**N77-30536\*** National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio.

### **INTRODUCTION TO BASIC SOLAR CELL MEASUREMENTS**

Henry W. Brandhorst, Jr. *In its Terrest. Photovoltaic Meas., 2* 1976 p 275-300 refs Previously announced as N77-26625 (For primary document see N77-30521 21-42)

Avail: NTIS HC A17/MF A01 CSCL 10A

For abstract, see N77-26625 on page 137.

**N77-30538\*** National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio.

### **INDOOR AND OUTDOOR MEASUREMENTS OF PERFORMANCE OF PHOTOVOLTAIC ARRAYS**

Henry B. Curtis *In its Terrest. Photovoltaic Meas., 2* 1976 p 309-322 refs Previously announced as N77-26626 (For primary document see N77-30521 21-42)

Avail: NTIS HC A17/MF A01 CSCL 10A

For abstract, see N77-26626 on page 137.

## 43 EARTH RESOURCES

Includes remote sensing of earth resources by aircraft and spacecraft; photogrammetry; and aerial photography. For instrumentation see 35 *Instrumentation and Photography*.

**N77-16415\*** National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio.

### UTILITY OF A SCANNING DENSITOMETER IN ANALYZING REMOTELY SENSED IMAGERY

Joyce T. Dooley Dec 1976 21 p refs  
(NASA-TM-X-73533, E-8955) Avail: NTIS HC A02/MF A01 CSCL 05B

The utility of a scanning densitometer for analyzing imagery in the NASA Lewis Research Center's regional remote sensing program was evaluated. Uses studied include: (1) quick-look screening of imagery by means of density slicing, magnification, color coding, and edge enhancement; (2) preliminary category classification of both low- and high-resolution data bases; and (3) quantitative measurement of the extent of features within selected areas. The densitometer was capable of providing fast, convenient, and relatively inexpensive preliminary analysis of aerial and satellite photography and scanner imagery involving land cover, water quality, strip mining, and energy conservation.

Author

**N77-21518\*** National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio.

### APPLICATION OF REMOTE THERMAL SCANNING TO THE NASA ENERGY CONSERVATION PROGRAM

Robert L. Bowman and John R. Jack Jan. 1977 25 p refs  
Original contains color illustrations  
(NASA-TM-X-73570, E-9017) Avail: NTIS HC A02/MF A01 CSCL 08B

Airborne thermal scans of all NASA centers were made during 1975 and 1976. The remotely sensed data were used to identify a variety of heat losses, including those from building roofs and central heating system distribution lines. Thermal imagery from several NASA centers is presented to demonstrate the capability of detecting these heat losses remotely. Many heat loss areas located by the scan data were verified by ground surveys. At this point, at least for such energy-intensive areas, thermal scanning is an excellent means of detecting many possible energy losses.

Author

**N77-26577\*** Stanford Research Inst., Menlo Park, Calif.  
**MICROWAVE PROPERTIES OF ICE FROM THE GREAT LAKES** Final Report

R. S. Vickers Jan 1975 36 p refs  
(Contract NAS3-19092, SRI Proj. 3571)  
(NASA-CR-135222) Avail: NTIS HC A03/MF A01 CSCL 08L

The increasing use of radar systems as remote sensors of ice thickness has revealed a lack of basic data on the microwave properties of fresh-water ice. A program, in which the complex dielectric constant was measured for a series of ice samples taken from the Great Lakes, is described. The measurements were taken at temperatures of -5, -10, and -15 C. It is noted that the ice has considerable internal layered structure, and the effects of the layering are examined. Values of 3.0 to 3.2 are reported for the real part of the dielectric constant, with an error bar of  $\pm$  or - 0.01.

Author

## 44 ENERGY PRODUCTION AND CONVERSION

Includes specific energy conversion systems, e.g., fuel cells and batteries, global sources of energy, fossil fuels, geophysical conversion: hydroelectric power, and wind power.

For related information see also 07 Aircraft Propulsion and Power, 20 Spacecraft Propulsion and Power, 28 Propellants and Fuels, and 85 Urban Technology and Transportation

**N77-10640\*** National Aeronautics and Space Administration, Lewis Research Center, Cleveland, Ohio.

### EARLY OPERATION EXPERIENCE ON THE ERDA/NASA 100 kW WIND TURBINE

John C. Glasgow and Bradford S. Linscott Sep. 1976 25 p refs

(NASA-TM-X-71601; E-8076) Avail: NTIS HC A02/MF A01 CSCL 10A

As part of the Energy Research and Development Administration (ERDA) wind energy program, NASA Lewis Research Center is testing an experimental 100-kW wind turbine. Rotor blade and drive shaft loads and tower deflection were measured during operation of the wind turbine at rated rpm. The blade loads measured are higher than anticipated. Preliminary results indicate that air flow blockage by the tower structure probably caused the high rotor blade bending moments. Author

**N77-10641\*** National Aeronautics and Space Administration, Lewis Research Center, Cleveland, Ohio.

### SERIES-PARALLEL METHOD OF DIRECT SOLAR ARRAY REGULATION

S. T. Gooder Sep. 1976 16 p refs

(NASA-TM-X-73505; E-8906) Avail: NTIS HC A02/MF A01 CSCL 10A

A 40 watt experimental solar array was directly regulated by shorting out appropriate combinations of series and parallel segments of a solar array. Regulation switches were employed to control the array at various set-point voltages between 25 and 40 volts. Regulation to within  $\pm 0.5$  volt was obtained over a range of solar array temperatures and illumination levels as an active load was varied from open circuit to maximum available power. A fourfold reduction in regulation switch power dissipation was achieved with series-parallel regulation as compared to the usual series-only switching for direct solar array regulation. Author

**N77-10642\*** National Aeronautics and Space Administration, Lewis Research Center, Cleveland, Ohio.

### A SUMMARY OF THE ECAS MHD POWER PLANT RESULTS

George R. Soikel and L. P. Harris (GE Co., Schenectady, N. Y.) 1976 24 p refs Presented at the 3d US-USSR Colloq. on Magnetohydrodyn., Moscow, 21-22 Oct. 1976

(NASA-TM-X-73491; E-8884) Avail: NTIS HC A02/MF A01 CSCL 10B

The performance and the cost of electricity (COE) for MHD systems utilizing coal or coal derived fuels are summarized along with a conceptual open cycle MHD plant design. The results show that open cycle coal fired recuperatively preheated MHD systems have potentially one of the highest coal-pile-to-bus bar efficiencies (48.3%) and also one of the lowest COE of the systems studied. Closed cycle, inert gas systems do not appear to have the potential of exceeding the efficiency of or competing with the COE of advanced steam plants. Author

**N77-10645\*** National Aeronautics and Space Administration, Lewis Research Center, Cleveland, Ohio.

### SOLAR CELL SHINGLE Patent Application

Americo F. Forestieri, Anthony F. Ratajczak, and Leroy G. Sidorak, inventors (to NASA) Filed 24 Aug. 1976 11 p

(NASA-Case-LEW-12587-1; US-Patent-Appl-SN-717319) Avail: NTIS HC A02/MF A01 CSCL 10A

A solar cell shingle may be made of an array of solar cells on a lower portion of a substantially rectangular shingle substrate made of fiberglass cloth or the like. The solar cells may be encapsulated in fluorinated ethylene propylene or some other weatherproof translucent or transparent encapsulant to form a combined electrical module and a roof shingle. The interconnected solar cells are connected to connectors at the edge of the substrate through a connection to a common electrical bus or busses. An overlap area is arranged to receive the overlap of a cooperating similar shingle so that the cell portion of the cooperating shingle may overlie the overlap area of the roof shingle. Accordingly the same shingle serves the double function of an ordinary roof shingle which may be applied in the usual way and an array of cooperating solar cells from which electrical energy may be collected. NASA

**N77-11529\*** National Aeronautics and Space Administration, Lewis Research Center, Cleveland, Ohio.

### OPTIMIZED SELECTIVE COATINGS FOR SOLAR COLLECTORS

G. McDonald and Henry B. Curtis Jun. 1967 12 p refs Presented at the Am. Electroplaters Soc., Denver, 29 Jun. 1976

(NASA-TM-X-73498; E-8896) Avail: NTIS HC A02/MF A01 CSCL 10A

The spectral reflectance properties of black nickel electroplated over stainless steel and of black copper produced by oxidation of copper sheet were measured for various plating times of black nickel and for various lengths of time of oxidation of the copper sheet, and compared to black chrome over nickel and to converted zinc. It was determined that there was an optimum time for both plating of black nickel and for the oxidation of copper black. At this time the solar selective properties show high absorptance in the solar spectrum and low emittance in the infrared. The conditions are compared for production of optimum optical properties for black nickel, black copper, black chrome, and two black zinc conversions which at the same conditions had absorptances of 0.84, 0.90, 0.95, 0.84, and 0.92, respectively, and emittances of 0.18, 0.08, 0.09, 0.10, and 0.08, respectively. Author

**N77-11530\*** National Aeronautics and Space Administration, Lewis Research Center, Cleveland, Ohio.

### EVALUATION OF FLAT-PLATE COLLECTOR EFFICIENCY UNDER CONTROLLED CONDITIONS IN A SOLAR SIMULATOR

Susan M. Johnson and Frederick Simon 1976 19 p refs Presented at the Intern. Solar Energy Soc. Conf., Winnipeg, Canada, 15-20 Aug. 1976

(NASA-TM-X-73520; E-8932) Avail: NTIS HC A02/MF A01 CSCL 10A

The measured thermal efficiencies of 35 collectors tested with a solar simulator, along with the correlation equations used to generalize the data, are presented. The single correlation used is shown to apply to all the different types of collectors tested, including one with black paint and one cover, one with a selective surface coating and two covers, and an evacuated-tube collector. The test and correlation technique is also modified by using a shield so that collectors larger than the simulator test area can also be tested. This technique was verified experimentally for a shielded collector for which the collector shielded area was 31% of the solar simulator radiation area. A table lists all the collectors tested, the collector areas, and the experimental constants used to correlate the data for each collector. Author

**N77-12517\*** National Aeronautics and Space Administration.  
Lewis Research Center, Cleveland, Ohio.

**SPACE-TO-EARTH POWER TRANSMISSION SYSTEM**

Grady H. Stevens and Richard Schuh Nov. 1976 143 p refs  
(NASA-TM-X-73489; E-8885) Avail: NTIS HC A07/MF A01  
CSCL 10A

A preliminary analysis was conducted to establish the requirements of a space-to-earth microwave power transmission system. The need for accurate phase control on the transmitter was established and methods for assessing the impact of power density and thermal constraints on system performance were demonstrated. Potential radio frequency interference was considered. The sensitivity of transmission system scale to variations in power source, transportation and orbital fabrication and assembly costs was also determined. Author

**N77-12518\*** National Aeronautics and Space Administration.  
Lewis Research Center, Cleveland, Ohio.

**MEASURED PERFORMANCE OF A 3 TON LITHIUM ABSORPTION WATER CHILLER AND ITS EFFECT ON COOLING SYSTEM OPERATION**

David Namkoong 1976 10 p Presented at the Intern. Solar Energy Meeting, Winnipeg, Can., 15-20 Aug. 1976  
(NASA-TM-X-73496; E-8894) Avail: NTIS HC A02/MF A01  
CSCL 10A

A three ton lithium bromide absorption water chiller was tested for a number of conditions involving hot water input, chilled water, and the cooling water. The primary influences on chiller capacity were the hot water inlet temperature and the cooling water inlet temperature. One combination of these two parameters extended the output to as much as 125% of design capacity, but no combination could lower the capacity to below 60% of design. A cooling system was conceptually designed so that it could provide several modes of operation. Such flexibility is needed for any solar cooling system to be able to accommodate the varying solar energy collection and the varying building demand. It was concluded that a three-ton absorption water chiller with the kind of performance that was measured can be incorporated into a cooling system such as that proposed, to provide efficient cooling over the specified ranges of operating conditions. Author

**N77-12519\*** National Aeronautics and Space Administration.  
Lewis Research Center, Cleveland, Ohio.

**STATUS OF SILICON SOLAR CELL TECHNOLOGY**

Henry W. Brandhorst, Jr. 1976 17 p refs Presented at the 2d Intern. Conf. on Solid State Devices, Tokyo, 1-3 Sep. 1976; Sponsored by Japan. Soc. of Appl. Phys.  
(NASA-TM-X-73531; E-8956) Avail: NTIS HC A02/MF A01  
CSCL 10A

Major progress in solar cell technology leading to increased efficiency has occurred since 1970. Technical approaches leading to this increased output include surface texturing, improved antireflection coatings, reduced grid pattern area coverage, shallow junctions and back surface fields. The status of these developments and their incorporation into cell production is discussed. Future research and technology trends leading to further efficiency increases and substantial cost reductions are described. Author

**N77-12520\*** National Aeronautics and Space Administration.  
Lewis Research Center, Cleveland, Ohio.

**OUTDOOR PERFORMANCE RESULTS FOR NBS ROUND ROBIN COLLECTOR NO. 1**

Dean R. Miller Nov. 1976 10 p refs  
(NASA-TM-X-73547; E-8983) Avail: NTIS HC A02/MF A01  
CSCL 10A

The efficiency of a PPG flat-plate solar collector was evaluated utilizing an outdoor solar collector test facility at the NASA-Lewis Research Center, as part of the National Bureau of Standards 'round robin' collector test program. The correlation equation for collector thermal efficiency  $\eta$  as a function of the data was:  $\eta = 0.666 - 1.003(Btu/hr-sq ft-F) \Theta$ , where the parameter  $\Theta$  is the difference between the average fluid temperature and the ambient temperature, all divided by the total flux impinging on the collector. Author

**N77-12521\*** National Aeronautics and Space Administration.  
Lewis Research Center, Cleveland, Ohio.

**TEMPERATURE DISTRIBUTION OF A HOT WATER STORAGE TANK IN A SIMULATED SOLAR HEATING AND COOLING SYSTEM**

David Namkoong Nov. 1976 17 p refs  
(NASA-TM-X-73549; E-8985) Avail: NTIS HC A02/MF A01  
CSCL 10A

A 2,300-liter hot water storage tank was studied under conditions simulating a solar heating and cooling system. The initial condition of the tank, ranging from 37 C at the bottom to 94 C at the top, represented a condition midway through the start-up period of the system. During the five-day test period, the water in the tank gradually rose in temperature but in a manner that diminished its temperature stratification. Stratification was found not to be an important factor in the operation of the particular solar system studied. Author

**N77-12522\*** National Aeronautics and Space Administration.  
Lewis Research Center, Cleveland, Ohio.

**THE REDOX FLOW SYSTEM FOR SOLAR PHOTOVOLTAIC ENERGY STORAGE**

Patricia O'Donnell and Randall F. Gahn 1976 9 p refs Presented at the Twelfth Photovoltaic Specialists Conf. sponsored by the Inst. of Elec. and Electron. Eng., Baton Rouge, La., 15-18 Nov. 1976

(NASA-TM-X-73562; E-9006) Avail: NTIS HC A02/MF A01  
CSCL 10A

A new method of storage was applied to a solar photovoltaic system. The storage method is a redox flow system which utilizes the oxidation-reduction capability of two soluble electrochemical redox couples for its storage capacity. The particular variant described separates the charging and discharging function of the system such that the electrochemical couples are simultaneously charged and discharged in separate parts of the system. The solar array had 12 solar cells, wired in order to give a range of voltages and currents. The system stored the solar energy so that a load could be run continually day and night. The main advantages of the redox system are that it can accept a charge in the low voltage range and produce a relatively constant output regardless of solar activity. Author

**N77-12523\*** National Aeronautics and Space Administration.  
Lewis Research Center, Cleveland, Ohio.

**ANALYSIS OF EPITAXIAL DRIFT FIELD N ON P SILICON SOLAR CELLS**

Cosmo R. Baraona and Henry W. Brandhorst, Jr. 1976 10 p Presented at the Twelfth Photovoltaic Specialists Conf. sponsored by the Inst. of Elec. and Electron. Eng., Baton Rouge, La., 15-18 Nov. 1976

(NASA-TM-X-73563; E-9007) Avail: NTIS HC A02/MF A01  
CSCL 10A

The performance of epitaxial drift field silicon solar cell structures having a variety of impurity profiles was calculated. These structures consist of a uniformly doped P-type substrate layer, and a P-type epitaxial drift field layer with a variety of field strengths. Several N-layer structures were modeled. A four layer solar cell model was used to calculate efficiency, open circuit voltage and short circuit current. The effect on performance of layer thickness, doping level, and diffusion length was determined. The results show that peak initial efficiency of 18.1% occurs for a drift field thickness of about 30 micron with the doping rising from 10 to the 17th power atoms/cu cm at the edge of the depletion region to 10 to the 18th power atoms/cu cm in the substrate. Stronger drift fields (narrow field regions) allowed very high performance (17% efficiency) even after irradiation to 3x10 to the 14th power 1 MeV electrons/sq cm. Author

**N77-13534\*** National Aeronautics and Space Administration.  
Lewis Research Center, Cleveland, Ohio.

**WIND TUNNEL MEASUREMENTS OF THE TOWER SHADOW ON MODELS OF THE ERDA/NASA 100 KW WIND TURBINE TOWER**

Joseph M. Savino and Lee H. Wagner Nov. 1976 37 p  
(NASA-TM-X-73548; E-8984) Avail: NTIS HC A03/MF A01  
CSCL 10B

Detailed wind speed profile measurements were made in the wake of 1/25 scale and 1/48 scale tower models to determine the magnitude of the speed reduction (the tower shadow). The 1/25 scale tower modeled closely the actual wind turbine including the service stairway and the equipment elevator rails on one face. The 1/48 scale model was made of all tubular members. Measurements were made on the 1/25 scale model with and without the stairway and elevator rails, and on the 1/48 all tube model without stairs and rails. The test results show that the stairs and rails were a major source of wind flow blockage. The all tubular 1/48 scale tower was found to offer less resistance to the wind than the 1/25 scale model that contained a large number of square sections. Shadow photos are included to show the extent of the blockage offered to the wind from various directions.

Author

**N77-13535\*** National Aeronautics and Space Administration.  
Lewis Research Center, Cleveland, Ohio.

**STANDARDIZED PERFORMANCE TESTS OF COLLECTORS OF SOLAR THERMAL ENERGY - A FLAT-PLATE COPPER COLLECTOR WITH PARALLEL MYLAR STRIPING**

Susan M. Johnson Nov. 1976 8 p ref  
(NASA-TM-X-73553; E-8991) Avail: NTIS HC A02/MF A01  
CSCL 10A

Basic test results are reported for a flat plate solar collector whose performance was determined in a solar simulator. The collector was tested over ranges of inlet temperatures, fluxes and one coolant flow rate. Collector efficiency is correlated in terms of inlet temperature and flux level.

Author

**N77-13536\*** National Aeronautics and Space Administration.  
Lewis Research Center, Cleveland, Ohio.

**STANDARDIZED PERFORMANCE TESTS OF COLLECTORS OF SOLAR THERMAL ENERGY: AN EVACUATED FLAT-PLATE COPPER COLLECTOR WITH A SERPENTINE FLOW DISTRIBUTION**

Susan M. Johnson Nov. 1976 8 p ref  
(NASA-TM-X-73415; E-9001) Avail: NTIS HC A02/MF A01  
CSCL 10A

Basic test results are given for a flat plate solar collector whose performance was determined in the NASA-Lewis solar simulator. The collector was tested over ranges of inlet temperatures, fluxes and one coolant flow rate. Collector efficiency is correlated in terms of inlet temperature and flux level.

Author

**N77-13537\*** National Aeronautics and Space Administration.  
Lewis Research Center, Cleveland, Ohio.

**STATUS OF THE ERDA/NASA PHOTOVOLTAIC TESTS AND APPLICATIONS PROJECT**

J. N. Deyo, H. W. Brandhorst, Jr., and A. F. Forestieri 18 Nov. 1976 10 p Presented to the 12th Photovoltaic Specialists Conf., 15-18 Nov. 1976; sponsored by the Inst. of Electrical and Electronic Engineers  
(NASA-TM-X-73567) Avail: NTIS HC A02/MF A01 CSCL 10A

The Tests and Applications Project of the ERDA Photovoltaic Program is concerned with the testing of photovoltaic systems and the growth of their use in real terrestrial applications. This activity is an important complement to the development of low cost solar arrays by providing requirements based on application needs and stimulating markets to create demand to absorb increasing production capacity. A photovoltaic system test facility is now operational, market stimulation has been initiated through applications, and standards for terrestrial cell measurements established.

Author

**N77-13538\*** National Aeronautics and Space Administration  
Lewis Research Center, Cleveland, Ohio.

**AN EXPERIMENTAL INVESTIGATION WITH ARTIFICIAL SUNLIGHT OF A SOLAR HOT-WATER HEATER**

Frederick F. Simon 20 Aug. 1976 20 p refs Presented at the Joint Conf. of the Intern. Solar Energy Soc and the Solar Energy Soc. of Can., Winnipeg, Can., 15-20 Aug 1976  
(NASA-TM-X-73534; E-8959) Avail: NTIS HC A02/MF A01  
CSCL 10A

Thermal performance measurements were made of a commercial solar hot water heater in a solar simulator to determine basic performance characteristics of a traditional type of flat plate collector, with and without side reflectors (to increase the solar flux). Information on each of the following was obtained: (1) the effect of flow and incidence angle on the efficiency of a flat plate collector (but only without side reflectors); (2) transient performance under flow and nonflow conditions; (3) the effectiveness of reflectors to increase collector efficiency for a zero radiation angle at fluid temperatures required for solar air conditioning; and (4) the limits of applicability of a collector efficiency correlation based on the Hottel Whillier equation.

Author

**N77-14580\*** National Aeronautics and Space Administration  
Lewis Research Center, Cleveland, Ohio.

**SILICON NITRIDE COATED, PLASTIC COVERED SOLAR CELL Patent**

Jacob D. Broder, inventor (to NASA) Issued 7 Dec. 1976 4 p  
Filed 30 Dec. 1975 Supersedes N76-14613 (14 . 05, p 0604)

(NASA-Case-LEW-11496-1; US-Patent-3,996,067;  
US-Patent-Appl-SN-645508; US-Patent-Class-136-89;  
US-Patent-Class-204-192) Avail: US Patent Office CSCL 10A

A non-oxide anti-reflective coating was used with a transparent plastic cover of fluorinated ethylene propylene copolymer on a silicon solar cell to increase the resistance to damage caused by electron bombardment.

Official Gazette of the U.S. Patent Office

**N77-14581\*** National Aeronautics and Space Administration  
Lewis Research Center, Cleveland, Ohio.

**ELECTRICALLY RECHARGEABLE REDOX FLOW CELL Patent**

Lawrence H. Thaller, inventor (to NASA) Issued 7 Dec. 1976 6 p Filed 22 Aug. 1975 Supersedes N75-32586 (13 . 23, p 2938)

(NASA-Case-LEW-12220-1; US-Patent-3,996,064;  
US-Patent-Appl-SN-606891; US-Patent-Class-320-2;  
US-Patent-Class-429-23; US-Patent-Class-429-34) Avail: US Patent Office CSCL 10C

A bulk energy storage system is designed with an electrically rechargeable reduction-oxidation (REDOX) cell divided into two compartments by a membrane, each compartment containing an electrode. An anode fluid is directed through the first compartment at the same time that a cathode fluid is directed through the second compartment. Means are provided for circulating the anode and cathode fluids, and the electrodes are connected to an intermittent or non-continuous electrical source, which when operating, supplies current to a load as well as to the cell to recharge it. Ancillary circuitry is provided for disconnecting the intermittent source from the cell at prescribed times and for circulating the anode and cathode fluids according to desired parameters and conditions.

Official Gazette of the U.S. Patent Office

**N77-14585\*** National Aeronautics and Space Administration  
Lewis Research Center, Cleveland, Ohio.

**NEW SEPARATORS FOR NICKEL-ZINC BATTERIES**

Dean W. Sheibley Washington Dec. 1976 20 p refs  
(NASA-TM-X-3465; E-8915) Avail: NTIS HC A02/MF A01  
CSCL 10C

Flexible separators consisting of a substrate coated with a mixture of a polymer and organic and inorganic additives were

cycle tested in nickel-zinc cells. By substituting a rubber-based resin for polyphenylene oxide in the standard inorganic-organic separator, major improvements in both cell life and flexibility were made. Substituting newsprint for asbestos as the substrate shows promise for use on the zinc electrode and reduces separator cost. The importance of ample electrolyte in the cells was noted. Cycle lives and the characteristics of these flexible, low-cost separators were compared with those of a standard microporous polypropylene separator. Author

**N77-15487\*** National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio.  
**PERFORMANCE CORRELATIONS OF FIVE SOLAR COLLECTORS TESTED SIMULTANEOUSLY OUTDOORS**  
 Drsn R. Miller 1976 26 p Presented at the Joint Conf. of the Intern. Solar Energy Soc. and the Solar Energy Soc. of Canada, Winnipeg, Canada, 15-20 Aug. 1976  
 (NASA-TM-X-73548; E-8982) Avail. NTIS HC A03/MF A01 CSCL 10A

Collector thermal efficiency, and efficiency degradation with time were measured for 5 flat-plate solar collectors tested simultaneously in an outdoor solar collector test facility. Results indicate that by using collector performance parameters which account for diffuse isolation, outdoor data recorded on cloud days can be used as a measure of performance, as long as the ratio of direct to total insolation exceeds approximately 0.6. These outdoor results also show good agreement with thermal efficiency data obtained indoors in a solar simulator. Significant efficiency degradation occurred on only one of the five collectors exposed to outdoor conditions for a period of one to two years. Author

**N77-15490\*** National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio.  
**ENCAPSULATED SOLAR CELL MODULES Patent Application**  
 Evelyn Anagnostou and Americo F. Forestieri, inventors (to NASA) Filed 30 Nov. 1976 9 p  
 (NASA-Case-LEW-12185-1; US-Patent-Appl-SN-746269) Avail. NTIS HC A02/MF A01 CSCL 10A

A procedure is described in which the electrical connections to solar cells in a module are made at the same time the cells are encapsulated for protection. The encapsulating material is embossed to facilitate the positioning of the cells during assembly. NASA

**N77-16445\*** National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio.  
**VELOCITY AND TEMPERATURE DISTRIBUTIONS OF COAL-SLAG LAYERS ON MAGNETOHYDRODYNAMIC GENERATORS WALLS**  
 Carlson C. P. Pian and J. Marlin Smith Jan. 1977 19 p refs  
 (NASA-TN-D-8396; E-8929) Avail. NTIS HC A02/MF A01 CSCL 10B

Approximate analytical expressions are derived for the velocity and temperature distributions in steady state coal slag deposits flowing over MHD generator walls. Effects of slag condensation and Joule heating are included in the analysis. The transport conditions and the slag temperature at the slag-gas interface are taken to be known parameters in the formulation. They are assumed to have been predetermined either experimentally or from the slag properties and the gas dynamic calculations of the free stream flow. The analysis assumes a power law velocity profile for the slag and accounts for the coupling between the energy and momentum conservation equations. Comparisons are made with the more exact numerical solutions to verify the accuracy of the results. Author

**N77-17563\*** National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio.  
**INSPECTION OF TWO BRAYTON ROTATING UNITS AFTER EXTENSIVE ENDURANCE TESTING**  
 James H. Dunn Dec. 1976 25 p refs  
 (NASA-TM-X-73569; E-9013) Avail. NTIS HC A02/MF A01 CSCL 10B

A system was designed to produce 2-10 kW net continuous electric power for at least 5 years. The turbine-alternator-compressor power conversion unit in the system is designated Brayton Rotating Unit (BRU). Four BRU's were fabricated and extensively tested. One BRU has accumulated 11,000 hours of operation, and another has accumulated in excess of 21,000 hours. Testing has demonstrated that the BRU's have met or exceeded performance objectives. Two BRU's were disassembled and given a thorough post-test inspection. The inspection results show that after 21,000 hours of operation there is no apparent wear or failure mode that will prevent the attainment of the 5-year life objective. Author

**N77-17564\*** National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio.  
**SOLAR CELL COLLECTOR AND METHOD FOR PRODUCING SAME Patent Application**  
 John C. Evans, Jr., inventor (to NASA) Filed 22 Feb. 1977 16 p  
 (NASA-Case-LEW-12552-1; US-Patent-Appl-SN-776869) Avail. NTIS HC A02/MF A01 CSCL 10A

A method is described which permits the formation of highly conductive metal channels in a continuous pattern of any desired design within a transparent conductive mixed oxide layer which covers and protects an underlying photovoltaic substrate. The result is a sufficient collector system for the current generated by incident photon radiation. NASA

**N77-17565\*** National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio.  
**IMPROVED BACKWALL CELL Patent Application**  
 Henry W. Brandhorst, Jr., inventor (to NASA) Filed 19 Jan. 1977 15 p  
 (NASA-Case-LEW-12236-1; US-Patent-Appl-SN-760771) Avail. NTIS HC A02/MF A01 CSCL 10A

A solar cell is described having a first material of one conductivity type with one face having the same conductivity type more heavily doped to form a field region to receive the radiant energy. A layer of opposite conductivity type or a metallic layer forming a Schottky barrier is applied to the opposite face. A gridded contact pervious to the radiant energy may be applied to the region of the more heavily doped material for electrical contact. The device allows separate control of the junction, either the p-n junction or the Schottky diode junction, and the efficient collection of light. This efficiency is improved, because the high conductivity region has low sheet resistance, and a low surface recombination velocity with enhanced effective diffusion lengths in bulk. NASA

**N77-18560\*** National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio.  
**FORMULATED PLASTIC SEPARATORS FOR SOLUBLE ELECTRODE CELLS Patent Application**  
 Dean W. Shebley, inventor (to NASA) Filed 10 Mar 1977 22 p  
 (NASA-Case-LEW-12358-1; US-Patent-Appl-SN-776146) Avail. NTIS HC A02/MF A01 CSCL 10C

A rubber ion transport sheeting material formulated with o. without a flexible and porous substrate is described for use as the membrane between the acid compartments of a redox couple in a bulk electrical energy storage system. The membrane exhibits minimal increases in resistivity with the passage of time and prevents the accumulation of unequal amounts of water between the two sides of the redox cell. NASA

**N77-19571\*** National Aeronautics and Space Administration  
Lewis Research Center, Cleveland, Ohio.

**SOLAR CELL ASSEMBLY Patent**

Henry W. Brandhorst, Jr., inventor (to NASA) Issued 2 Nov. 1976 5 p Filed 30 Sep. 1974 Supersedes N74-33484 (12-23, p 2775)

(NASA-Case-LEW-11549-1; US-Patent-3,989,547;

US-Patent-Appl-SN-510677; US-Patent-Class-136-89) Avail. US Patent Office CSCL 10A

The solar cell assembly includes a solar cell having an overlay of a semi-transparent coating of a metal, such as aluminum or silver, which covers the entire surface thereof. The purpose of the coating is to lower the amount of incident radiation on the cell and thereby lower cell temperature. The use of the semi-transparent coating over the entire cell surface uniformly limits incident radiation and hence reduces cell heat without any temperature gradients. The coating also lowers series cell resistance. The coating may be directly deposited on the cell surface or on the undersurface of a cover plate bonded to the cell.

Official Gazette of the U.S. Patent Office

**N77-19580\*** National Aeronautics and Space Administration,  
Lewis Research Center, Cleveland, Ohio.

**SYNCHRONIZATION OF THE ERDA-NASA 100 kW WIND TURBINE GENERATOR WITH LARGE UTILITY NETWORKS**

H. H. Hwang and Leonard J. Gilbert Jul. 1977 17 p refs Presented at the Control of Power Systems Conf., College Station Tex., 14-16 Mar. 1977; sponsored by IEEE

(NASA-TM-X-73613; E-9096) Avail. NTIS HC A02/MF A01 CSCL 10B

The synchronizing of a wind turbine generator against an infinite bus under random conditions is studied. With a digital computer, complete solutions for rotor speed, generator power angle, electromagnetic torque, wind turbine torque, wind turbine blade pitch angle, and armature current are obtained and presented by graphs.

Author

**N77-20563\*** National Aeronautics and Space Administration,  
Lewis Research Center, Cleveland, Ohio.

**SUMMER PERFORMANCE RESULTS OBTAINED FROM SIMULTANEOUSLY TESTING TEN SOLAR COLLECTORS OUTDOORS**

Dean R. Miller Feb. 1977 27 p refs

(NASA-TM-X-73594; E-9066) Avail. NTIS HC A03/MF A01 CSCL 10A

Ten solar collectors were simultaneously tested outdoors. Efficiency data were correlated using a method that separates solar variables (flux, incident angle) from the desired performance parameters (heat loss, absorbance, transmittance) which are unique to a given collector design. Tests were conducted on both clear and moderately cloudy days. Correlating data in the above manner, a 2-glass, black paint collector exhibited a decrease in efficiency of 5 percentage points relative to the baseline data for an exposure time of 2 years, 4 months. Condensation on the collector glazing was thought to be a contributing factor in this efficiency change.

Author

**N77-21548\*** National Aeronautics and Space Administration,  
Lewis Research Center, Cleveland, Ohio.

**APPLICATION OF THE SEM TO THE MEASUREMENT OF SOLAR CELL PARAMETERS**

Victor G. Weizer and Charles W. Andrews 1977 8 p refs Presented at 10th Ann. Scanning Electron Microscopy Symp., Chicago, 28 Mar. - 1 Apr. 1977; sponsored by IIT

(NASA-TM-X-73637; E-9138) Avail. NTIS HC A02/MF A01 CSCL 10A

Techniques are described which make use of the SEM to measure the minority carrier diffusion length and the metallurgical junction depth in silicon solar cells. The former technique permits the measurement of the true bulk diffusion length through the application of highly doped field layers to the back surfaces of the cells being investigated. It is shown that the secondary emission contrast observed in the SEM on a reverse-biased diode

can depict the location of the metallurgical junction if the diode has been prepared with the proper beveled geometry. The SEM provides the required contrast and the option of high magnification, permitting the measurement of extremely shallow junction depths.

Author

**N77-21549\*** National Aeronautics and Space Administration,  
Lewis Research Center, Cleveland, Ohio.

**RESULTS OF BASELINE TESTS OF THE EVA METRO SEDAN, CITI-CAR, JET INDUSTRIES ELECTRA-VAN, CDA TOWN CAR, AND OTIS P-500 VAN**

Francis J. Stenger, John M. Bozak, and Richard F. Soltis Oct. 1976 78 p

(Contract E(49-28)-1011)

(NASA-TM-X-73638; E-9140) Avail. NTIS HC A05/MF A01 CSCL 10B

Five electric vehicles were tested at vehicle test tracks using the SAE. The tests provide range data at steady speeds and for several driving cycles. Most tests were conducted with lead-acid traction batteries. The Otis Van and the Copper Electric Town Car were also tested with lead-acid and nickel-zinc batteries. The tests showed a range increase of from 82 to 101 percent depending on vehicle, speed, and test cycle.

Author

**N77-21643\*** National Aeronautics and Space Administration,  
Lewis Research Center, Cleveland, Ohio.

**ENERGY STORAGE POSSIBILITIES OF ATOMIC HYDROGEN**

R. D. Ertter (Colorado State Univ., Ft. Collins), J. V. Dugan, Jr. (Science and Tech. Comm., Washington, D. C.), and R. Palmer. In Miami Univ. First World Hydrogen Energy Conf. Proc., Vol. 3 Mar. 1976 18 p refs (For primary document see N77-21826 12-44)

Avail. NTIS HC A99/MF A01

Several recent experiments designed to produce and store macroscopic quantities of atomic hydrogen are discussed. The bulk ground state properties of atomic hydrogen, deuterium, and tritium systems are calculated assuming that all pair interactions occur via the atomic triplet potential. The conditions required to obtain this system, including inhibition of recombination through the energetically favorable singlet interaction, are discussed. The internal energy, pressure, and compressibility are calculated applying the Monte Carlo technique with a quantum mechanical variational wavefunction. The system studied consisted of 32 atoms in a box with periodic boundary conditions. Results show that atomic triplet hydrogen and deuterium remain gaseous at 0 K, i.e., the internal energy is positive at all molar volumes considered.

Author

**N77-22606\*** National Aeronautics and Space Administration,  
Lewis Research Center, Cleveland, Ohio.

**GELS AS BATTERY SEPARATORS FOR SOLUBLE ELECTRODE CELLS Patent**

Dean W. Sheibley and Randall F. Gahn, inventors (to NASA) Issued 19 Apr. 1977 6 p Filed 20 Jul. 1976 Supersedes N76-28643 (19-44 p 24781)

(NASA-Case-LEW-12364-1; US-Patent-4,018,971;

US-Patent-Appl-SN-707124; US-Patent-Class-429-105;

US-Patent-Class-429-107; US-Patent-Class-429-190;

US-Patent-Class-253-317) Avail. US Patent Office CSCL 09C

Gels are formed from silica powders and hydrochloric acid. The gels are then impregnated into a polymeric foam and the resultant sheet material is then used in applications where the transport of chloride ions is desired. Specifically disclosed is the utilization of the sheet in electrically rechargeable redox flow cells which find application in bulk power storage systems.

Official Gazette of the U.S. Patent Office



**N77-22608\*** National Aeronautics and Space Administration  
Lewis Research Center, Cleveland, Ohio  
**PHOTOVOLTAIC SYSTEM TEST FACILITY ELECTROMAGNETIC INTERFERENCE MEASUREMENTS**

J. A. Johnson, F. P. Herke, Jr., and W. D. Knapp Apr 1977  
12 p ref

(Contract E(49-26)-1022)

(NASA-TM-X-73640; E-9142; ERDA/NASA-1022/77/11)  
Avail: NTIS HC A02/MF A01 CSCL 10A

Field strength measurements on a single row of panels indicates that the operational mode of the array as configured presents no radiated EMI problems. Only one relatively significant frequency band near 200 kHz showed any degree of intensity (9  $\mu\text{V}/\text{m}$  including a background level of 5  $\mu\text{V}/\text{m}$ ). The level was measured very near the array (at 20 ft distance) while Federal Communications Commission (FCC) regulations limit spurious emissions to 15  $\mu\text{V}/\text{m}$  at 1,000 ft. No field strength readings could be obtained even at 35 ft distant. Author:

**N77-22609\*** National Aeronautics and Space Administration  
Lewis Research Center, Cleveland, Ohio.

**ERDA/LEWIS RESEARCH CENTER PHOTOVOLTAIC SYSTEMS TEST FACILITY**

A. E. Forestieri, J. A. Johnson, W. D. Knapp, H. Rigo, J. Stover, and R. Suhay Apr 1977 34 p

(Contract E(49-26)-1022)

(NASA-TM-X-73641; E-9147; ERDA/NASA-1022/77/12)  
Avail: NTIS HC A03/MF A01 CSCL 10A

A national photovoltaic power systems test facility (of initial 10-kW peak power rating) is described. It consists of a solar array to generate electrical power, test hardware for several alternate methods of power conversion, electrical energy storage systems, and an instrumentation and data acquisition system. Author

**N77-22610\*** National Aeronautics and Space Administration  
Lewis Research Center, Cleveland, Ohio.

**REAL TIME OUTDOOR EXPOSURE TESTING OF SOLAR CELL MODULES AND COMPONENT MATERIALS**

Evelyn Anagnostou and America F. Forestieri Apr 1977 13 p  
(Contract E(49-26)-1022)

(NASA-TM-X-73655; ERDA/NASA-1022/77/10) Avail: NTIS HC A02/MF A01 CSCL 10A

Plastic samples, solar cell modules, and sub-modules were exposed at test sites in Florida, Arizona, Puerto Rico, and Cleveland, Ohio, in order to determine materials suitable for use in solar cell modules with a proposed 20-year lifetime. Various environments were encountered including subtropical, subtropical with a sea air atmosphere, desert, rain forest, normal urban, and urban-polluted. The samples were exposed for periods up to six months. Materials found not suitable were polyurethane, polyester, Kapton, Mylar, and UV-stabilized Lexan. Suitable materials were acrylic, FEP-A, and glass. The results of exposure of polyvinylidene fluoride were dependent on the specific formulation, but several types appear suitable. RTV silicone rubber (clear) appears to pick up and hold dirt both as a free film and as a potting medium for modules. The results indicate that dirt accumulation and cleanability are important factors in the selection of solar cell module covers and encapsulants. Author

**N77-22615\*** National Aeronautics and Space Administration  
Lewis Research Center, Cleveland, Ohio.

**METHOD FOR PRODUCING SOLAR ENERGY PANELS BY AUTOMATION Patent Application**

John C. Evans, Jr., inventor (to NASA) Filed 25 Apr 1977  
24 p

(NASA-Case-LEW-12541-1; US-Patent-Appl-SN-790637) Avail: NTIS HC A02/MF A01 CSCL 10A

The solar cell panel is fabricated by photoetching a pattern of collector grid systems with appropriate interconnection and bus bar tabs into a glass or plastic sheet and then filling these regions with a first, thin conductive metal film followed by a layer of a mixed metal oxide such as  $\text{InAsO}$  or  $\text{InSnO}$ . A multiplicity of solar cells are bonded between the protective sheet at the

sites of the collector grid systems and a backelectrode substrate by conductive metal filled epoxy to complete the fabrication of an integrated solar panel. NASA

**N77-23604\*** National Aeronautics and Space Administration  
Lewis Research Center, Cleveland, Ohio.

**THE NASA THERMIONIC CONVERSION (TEC-ART) PROGRAM**

James F. Morris 1977 19 p refs Presented at Plasma Sci Conf., Troy, N. Y. 23-25 May 1977, sponsored by IEEE  
(NASA-TM-X-73610; E-9093) Avail: NTIS HC A02/MF A01 CSCL 10A

The current emphasis is on out-of-core thermionic conversion (TEC). The additional degrees of freedom offer new potentialities, but high-temperature material effects determine the level and lifetime of TEC performance. New electrodes not only raise power outputs but also maintain them regardless of emitter-vapor deposition on collectors in addition, effective electrodes serve compatibly with hot-shell alloys. Space TEC withstands external and internal high-temperature vaporization problems, and terrestrial TEC tolerates hot corrosive atmospheres outside and near-vacuum inside. Finally, reduction of losses between converter electrodes is essential even though rather demanding geometries appear to be required for some modes of enhanced operation. Author

**N77-23605\*** National Aeronautics and Space Administration  
Lewis Research Center, Cleveland, Ohio.

**THERMOCHEMICAL CYCLE ANALYSIS USING LINKED CECS72 AND HYDRGN COMPUTER PROGRAMS**

Leo F. Donovan May 1977 40 p refs

(NASA-TM-X-73667; E-9191) Avail: NTIS HC A03/MF A01 CSCL 10A

A combined thermochemical cycle analysis computer program was designed. Input to the combined program is the same as input to the thermochemical cycle analysis program except that the extent of the reactions need not be specified. The combined program is designed to be run interactively from a computer time-sharing terminal. This mode of operation allows correction or modification of the cycle to take place during cycle analysis. A group of 13 thermochemical cycles was used to test the combined program. Author

**N77-24587\*** National Aeronautics and Space Administration  
Lewis Research Center, Cleveland, Ohio.

**BASILINE PERFORMANCE OF SOLAR COLLECTORS FOR NASA LANGLEY SOLAR BUILDING TEST FACILITY**

Richard H. Knoll and Susan M. Johnson Washington May 1977 25 p refs

(NASA-TM-X-3505; E-9036) Avail: NTIS HC A02/MF A01 CSCL 10A

The solar collector field contains seven collector designs. Before operation in the field, the experimental performances (thermal efficiencies) of the seven collector designs were measured in an indoor solar simulator. The resulting data provided a baseline for later comparison with actual field test data. The simulator test results are presented for the collectors as received, and after several weeks of outdoor exposure with no coolant (dry operation). Six of the seven collector designs tested showed substantial reductions in thermal efficiency after dry operation. Author

**N77-24589\*** National Aeronautics and Space Administration  
Lewis Research Center, Cleveland, Ohio.

**APPLICATION OF SEMICONDUCTOR DIFFUSANTS TO SOLAR CELLS BY SCREEN PRINTING Patent Application**

John C. Evans, Jr., Henry W. Brandhorst, George A. Mazaris, and Larry R. Scudder, inventors (to NASA) Filed 20 May 1977  
18 p

(NASA-Case-LEW-12775-1; US-Patent-Appl-SN-799026) Avail: NTIS HC A02/MF A01 CSCL 10A

Diffusants are applied onto semiconductor solar cell substrates

using screen printing techniques. The method is applicable to square and rectangular cells and is used to apply dopants of opposite types to the front and back of the substrate. Then, simultaneous diffusion of both dopants is performed with a single furnace pass. **NASA**

**N77-24592\*#** National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio.

**EXPERIMENTAL EVALUATION OF A BREADBOARD HEAT AND PRODUCT-WATER REMOVAL SYSTEM FOR A SPACE-POWER FUEL CELL DESIGNED WITH STATIC WATER REMOVAL AND EVAPORATIVE COOLING**

Norman H. Hagedorn and Paul R. Prokiplus Washington May 1977 27 p ref  
(NASA-TN-D-8485; E-8822) Avail: NTIS HC A03/MF A01 CSCL 10A

A test program was conducted to evaluate the design of a heat and product-water removal system to be used with fuel cell having static water removal and evaporative cooling. The program, which was conducted on a breadboard version of the system, provided a general assessment of the design in terms of operational integrity and transient stability. This assessment showed that, on the whole, the concept appears to be inherently sound but that in refining this design, several facets will require additional study. These involve interactions between pressure regulators in the pumping loop that occur when they are not correctly matched and the question of whether an ejector is necessary in the system. **Author**

**N77-24593\*#** National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio.

**METHOD FOR FABRICATING SOLAR CELLS HAVING INTEGRAL COLLECTOR GRIDS** Patent Application

John C. Evans, Jr., inventor (to NASA) Filed 6 Jun. 1977 16 p  
(NASA-Case-LEW-12819-1; US-Patent-Appl-SN-803823) Avail: NTIS HC A02/MF A01 CSCL 10A

A heterojunction barrier photovoltaic device is described. It comprises a heterojunction or Schottky barrier device, a conductive base metal layer compatible with and coating predominately the exposed surface of the p-type substrate of the device such that a back surface field region is formed at the interface between the device and the base metal layer, a transparent, conductive mixed metal oxide layer in integral contact with the n-type layer of the heterojunction or Schottky barrier device having a metal alloy grid network of the same metal elements of the oxide constituents of the mixed metal oxide layer embedded in the mixed metal oxide layer, an insulating layer which prevents electrical contact between the conductive metal base layer and the transparent, conductive metal oxide layer, and a metal contact means covering the insulating layer and in intimate contact with the metal grid network embedded in the transparent, conductive oxide layer for conducting electrons generated by the photovoltaic process from the device. **NASA**

**N77-26612\*#** National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio.

**FACTORS AFFECTING THE OPEN-CIRCUIT VOLTAGE AND ELECTRODE KINETICS OF SOME IRON/TITANIUM REDOX FLOW CELLS**

Margaret A. Reid and Randall F. Gahn May 1977 17 p refs Presented at the Symp. on Electrode Mater. and Processes for Energy Conversion and Storage, Philadelphia, 8-13 May 1977; sponsored by the Electrochem. Soc., Inc.  
(Contract E(49-28)-1002)

(NASA-TM-X-73669; E-9193; ERDA/NASA-1002/77/10) Avail: NTIS HC A02/MF A01 CSCL 10C

Performance of the iron-titanium redox flow cell was studied as a function of acid concentration. Anion permeable membranes separated the compartments. Electrodes were graphite cloth. Current densities ranged up to 25 mA/square centimeter. Open-circuit and load voltages decreased as the acidity was increased on the iron side as predicted. On the titanium side, open-circuit voltages decreased as the acidity was increased.

ed in agreement with theory, but load voltages increased due to decreased polarization with increasing acidity. High acidity on the titanium side coupled with low acidity on the iron side gives the best load voltage, but such cells show voltage losses as they are repeatedly cycled. Analyses show that the bulk of the voltage losses are due to diffusion of acid through the membrane. **Author**

**N77-26613\*#** National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio.

**VIBRATION CHARACTERISTICS OF A LARGE WIND TURBINE TOWER ON NON-RIGID FOUNDATIONS**

Suey T. Yee, Tse-Young P. Cang, R. J. Scavuzzo, David H. Timmerman, and John W. Fenton May 1977 34 p refs  
(Contract E(49-26)-1004)  
(NASA-TM-X-73670; E-9194; ERDA/NASA-1004/77/1) Avail: NTIS HC A03/MF A01 CSCL 10A

Vibration characteristics of the Mod-OA wind turbine supported by nonrigid foundations were investigated for a range of soil rigidities. The study shows that the influence of foundation rotation on the fundamental frequency of the wind turbine is quite significant for cohesive soils or loose sand. The reduction in natural frequency can be greater than 20 percent. However, for a foundation resting on well graded, dense granular materials or bedrock, such effect is small and the foundation can be treated as a fixed base. **Author**

**N77-26614\*#** National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio.

**NEW BATTERIES AND THEIR IMPACT ON ELECTRIC VEHICLES**

Hayey J. Schwartz Apr. 1977 15 p refs Presented at Intern. Electric Vehicle Exposition, Chicago, 26-29 Apr. 1977; sponsored by Electric Vehicle Council Sponsored by ERDA  
(NASA-TM-X-73672; E-9197; ERDA/NASA-1011/77/3) Avail: NTIS HC A02/MF A01 CSCL 10C

The selection of batteries to power electric motor vehicles is discussed. The problem of evaluating battery performance and the availability of different batteries are considered. **D.M.L.**

**N77-26615\*#** National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio.

**PRELIMINARY RESULTS OF ACCELERATED EXPOSURE TESTING OF SOLAR CELL SYSTEM COMPONENTS**

Evelyn Anagnostou and Americo F. Forestieri May 1977 18 p  
(Contract E(49-26)-1022)  
(NASA-TM-X-73674; E-9200; ERDA/NASA-1022/77/14) Avail: NTIS HC A02/MF A01 CSCL 10A

Plastic samples and solar cell sub modules were exposed to an accelerated outdoor environment in Arizona and an accelerated simulated environment in a cyclic ultraviolet exposure tester which included humidity exposure. These tests were for preliminary screening of materials suitable for use in the manufacture of solar cell modules which are to have a 20-year lifetime. The samples were exposed for various times up to six months, equivalent to a real time exposure of four years. Suitable materials were found to be FEP-A, FEP-C, PFA, acrylic, silicone compounds and adhesives and possibly parylene. The method of packaging the sub modules was also found to be important to their performance. **Author**

**N77-26616\*#** National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio.

**MAGNETIC STIRLING CYCLES: A NEW APPLICATION FOR MAGNETIC MATERIALS**

Gerald V. Brown 6 Jun. 1977 6 p refs Presented at the Intern. Magnetics Conf., Los Angeles, 6-10 Jun. 1977; sponsored by the Inst. of Elec. and Electron. Eng.  
(NASA-TM-X-73676; E-9196) Avail: NTIS HC A02/MF A01 CSCL 10A

The elements of the cycle are summarized. The basic advantages include high entropy density in the magnetic material.

completely reversible processes, convenient control of the entropy by the applied field, the feature that heat transfer is possible during all processes, and the ability of the ideal cycle to attain Carnot efficiency. The mean field theory is used to predict the entropy of a ferromagnet in an applied field and also the isothermal entropy change and isentropic temperature change caused by applying a field. The results for isentropic temperature change are compared with experimental data on Gd. Coarse mixtures of ferromagnetic materials with different Curie points are proposed to modify the path of the cycle in the T-S diagram in order to improve the efficiency or to increase the specific power. Author

**N77-26617\*** National Aeronautics and Space Administration  
Lewis Research Center, Cleveland, Ohio.

**EVALUATION OF INITIAL COLLECTOR FIELD PERFORMANCE AT THE LANGLEY SOLAR BUILDING TEST FACILITY**

Robert J. Boyle, Ronald N. Jansen (NASA Langley, Hampton, Va.), and Richard H. Knoll Jun. 1977 22 p refs Presented at the 10th Ann. Meeting of the Am. Sect. of the Intern. Solar Energy Soc., Orlando, Fla (NASA-TM-X-73677) Avail NTIS HC A02/MF A01 CSCL 10A

The thermal performance of the solar collector field for the NASA Langley Solar Building Test Facility is given for October 1976 through January 1977. A 1,180 square meter solar collector field with seven collector designs helped to provide hot water for the building heating system and absorption air conditioner. The collectors were arranged in 12 rows with nominally 61 collectors per row. Heat transfer rates for each row were calculated and recorded along with sensor, insolation, and weather data every five minutes using a minicomputer. The agreement between the experimental and predicted collector efficiencies was generally within five percentage points. Author

**N77-26618\*** National Aeronautics and Space Administration  
Lewis Research Center, Cleveland, Ohio.

**TEST FACILITY FOR SOLAR-CELL REFERENCE CONDITIONS**

Thomas M. Klucher Nov. 1976 16 p refs Presented at 2d Ann. Photovoltaic Measurements Workshop, Baton Rouge, La. 10-12 Nov. 1976 (Contract E(49-26)-1022)

(NASA-CP-2010, ERDA/NASA-1022/76/1, TR-1-2) Avail NTIS HC A02/MF A01 CSCL 10A

A test facility, intended primarily for long-term monitoring of the global insolation and its components and the concurrent solar cell performance under a wide variety of measurable atmospheric and weather conditions, is described. Instruments for the measurement of insolation, cell performance, turbidity, water vapor, and cloud cover are described. Preliminary evaluation of the hourly data base generated over a two-month period for a range of sky conditions from clear to overcast is presented. Author

**N77-26619\*** National Aeronautics and Space Administration  
Lewis Research Center, Cleveland, Ohio.

**EFFECT OF ATMOSPHERIC PARAMETERS ON SILICON CELL PERFORMANCE**

Henry B. Curtis Nov. 1976 19 p refs Presented at 2d Ann. Photovoltaic Measurements Workshop, Baton Rouge, La. 10-12 Nov. 1976 (Contract E(49-26)-1022)

(NASA-CP-2010, ERDA/NASA-1022/76/2, TR-1-7) Avail NTIS HC A02/MF A01 CSCL 10A

The effects of changing atmospheric parameters on the performance of a typical silicon solar cell were calculated. The precipitable water vapor content, air mass and turbidity were varied over wide ranges and the normal terrestrial distribution of spectral irradiance was studied. The cell short-circuit current was then computed for each spectral irradiance distribution using the cell spectral response. Data are presented in the form of calibration number (cell current/incident irradiance) vs. water vapor content or turbidity. Author

**N77-26620\*** National Aeronautics and Space Administration  
Lewis Research Center, Cleveland, Ohio.

**ERRORS IN SHORT CIRCUIT MEASUREMENTS DUE TO SPECTRAL MISMATCH BETWEEN SUNLIGHT AND SOLAR SIMULATORS**

Henry B. Curtis 1976 26 p ref Presented at the 2d Ann. Photovoltaic Measurements Workshop, Baton Rouge, La. 10-12 Nov. 1976 (Contract E(49-26)-1022)

(NASA-CR-2010, ERDA/NASA-1022/76/3, TR-2-2) Avail NTIS HC A03/MF A01 CSCL 10A

Errors in short circuit current measurement were calculated for a variety of spectral mismatch conditions. The differences in spectral irradiance between terrestrial sunlight and three types of solar simulator were studied, as well as the differences in spectral response between three types of reference solar cells and various test cells. The simulators considered were a short arc xenon lamp AMO sunlight simulator, an ordinary quartz halogen lamp, and an ELH-type quartz halogen lamp. Three types of solar cells studied were a silicon cell, a cadmium sulfide cell and a gallium arsenide cell. Author

**N77-26621\*** National Aeronautics and Space Administration  
Lewis Research Center, Cleveland, Ohio.

**CONSIDERATION OF DESIGN AND CALIBRATION OF TERRESTRIAL REFERENCE SOLAR CELLS**

V. G. Weizer [1976] 28 p refs Presented at 2d Ann. Photovoltaic Measurements Workshop, Baton Rouge, La. 10-12 Nov. 1976 (Contract E(49-26)-1022)

(NASA-CP-2010, ERDA/NASA-1022/76/4, TR-2-4) Avail NTIS HC A03/MF A01 CSCL 10A

A discussion is presented on the problems encountered in the design of a reference cell that meets basic criteria, starting with basic design considerations, and proceeding with the precautions taken to ensure a global monitoring capability. The effects of the variations in atmospheric conditions on the calibration and use of reference cells are presented along with a discussion of the simplifications brought about by the use of spectrally matched test and reference cells. Finally, a method of matching test modules and arrays to reference cells by a red/blue response ratio technique is described. Author

**N77-26622\*** National Aeronautics and Space Administration  
Lewis Research Center, Cleveland, Ohio.

**SOME BASIC CONSIDERATIONS OF MEASUREMENTS INVOLVING COLLIMATED DIRECT SUNLIGHT**

An-Ti Chai Nov. 1976 17 p refs Presented at the 2d Ann. Photovoltaic Measurements Workshop, Baton Rouge, La. 10-12 Nov. 1976 (Contract E(49-26)-1022)

(NASA-CP-2010, ERDA/NASA-1022/76/5, TR-2-6) Avail NTIS HC A02/MF A01 CSCL 10A

The geometry of collimators for devices or instruments dealing with terrestrial direct sunlight is discussed. Effects of the opening angle and slope angle of a collimator on the measurements are investigated with regard to variations of turbidity and air mass. Based on this investigation, geometric dimensions for collimators and certain realistic terrestrial reference conditions are recommended for the purpose of solar cell calibration in terrestrial applications. Author

**N77-26623\*** National Aeronautics and Space Administration  
Lewis Research Center, Cleveland, Ohio.

**SENSITIVITY OF SOLAR-CELL PERFORMANCE TO ATMOSPHERIC VARIABLES. 1: SINGLE CELL**

Thomas M. Klucher [1976] 15 p refs Presented at 2d Ann. Photovoltaic Measurements Workshop, Baton Rouge, La. 10-12 Nov. 1976 (Contract E(49-26)-1022)

(NASA-CP-2010, ERDA/NASA-1022/76/6, TR-2-7) Avail NTIS HC A02/MF A01 CSCL 10A

The short circuit current of a typical silicon solar cell under direct solar radiation was measured for a range of turbidity, water vapor content, and air mass to determine the relation of

the solar cell calibration value (current-to-intensity ratio) to those atmospheric variables. A previously developed regression equation was modified to describe the relation between calibration value, turbidity, water vapor content, and air mass. Based on the value of the constants obtained by a least squares fit of the data to the equation, it was found that turbidity lowers the value, while increase in water vapor increases the calibration value. Cell calibration values exhibited a change of about 6% over the range of atmospheric conditions experienced. Author

**N77-26624\*** National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio.  
**SENSITIVITY OF SOLAR-CELL PERFORMANCE TO ATMOSPHERIC VARIABLES. 2: DISSIMILAR CELLS AT SEVERAL LOCATIONS**

Thomas M. Klucher and Russell E. Hart [1976] 16 p refs Presented at the 2d Ann. Photovoltaic Measurements Workshop, Baton Rouge, La., 10-12 Nov. 1976 (Contract E(49-26)-1022) (NASA-CP-2010; ERDA/NASA-1022/76/7; TR-2-8) Avail: NTIS HC A02/MF A01 CSCL 10A

Several solar cells having dissimilar spectral response curves and cell construction were measured at various locations in the United States to determine sensitivity of cell performance to atmospheric water vapor and turbidity. The locations selected represent a broad range of summer atmospheric conditions, from clear and dry to turbid and humid. Cell short circuit current under direct normal incidence sunlight, the intensity, water vapor and turbidity were measured. Regression equations were developed from the limited data base in order to provide a single method of prediction of cell current sensitivity to the atmospheric variables. Author

**N77-26625\*** National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio.  
**INTRODUCTION TO BASIC SOLAR CELL MEASUREMENTS**

Henry W. Brandhorst, Jr. [1976] 31 p refs Presented at 2d Ann. Photovoltaic Measurements Workshop, Baton Rouge, La., 10-12 Nov. 1976 (Contract E(49-26)-1022) (NASA-CP-2010; ERDA/NASA-1022/76/8; TR-3-1) Avail: NTIS HC A03/MF A01 CSCL 10A

The basic approaches to solar cell performance and diagnostic measurements are described. The light sources, equipment for I-V curve measurement, and the test conditions and procedures for performance measurement are detailed. Solar cell diagnostic tools discussed include analysis of I-V curves, series resistance and reverse saturation current determination, spectral response/quantum yield measurement, and diffusion length/lifetime determination. Author

**N77-26626\*** National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio.  
**INDOOR AND OUTDOOR MEASUREMENTS OF PERFORMANCE OF PHOTOVOLTAIC ARRAYS**

Henry B. Curtis [1976] 16 p refs Presented at the 2d Ann. Photovoltaic Measurements Workshop, Baton Rouge, La., 10-12 Nov. 1976 (Contract E(49-26)-1022) (NASA-CP-2010; ERDA/NASA-1022/76/9; TR-3-3) Avail: NTIS HC A02/MF A01 CSCL 10A

A description of the techniques and methodology for making outdoor I-V measurements of solar cells is given. Temperature and irradiance measurement, experimental arrangement, data acquisition system and I-V data transformations are discussed. Data are presented comparing outdoor measurements to indoor measurements using a pulsed solar simulator. Author

**N77-26678\*** National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio.

**EFFECTS OF OUTDOOR EXPOSURE ON SOLAR CELL MODULES IN THE ERDA/NASA LEWIS RESEARCH CENTER SYSTEMS TEST FACILITY**

I. Weinberg, Henry B. Curtis, and Americo F. Forestieri Apr. 1977 17 p refs (Contract E(49-26)-1022) (NASA-TM-X-73657; E-9173; ERDA/NASA-1022/77/13) Avail: NTIS HC A02/MF A01 CSCL 10A

The effects of outdoor exposure were determined by comparing standard I-V data obtained for the as-received modules with similar data obtained after removal from the field and cleaning with detergent solution. All modules measured in this way exhibited nonrecoverable degradation in P sub maximum varying from 4 to 7 percent. One module exposed for 41 days exhibited partial cell discoloration, loss of front surface metallization over the discolored portion, and a decrease in P sub maximum of 7 percent, tentatively attributed to cell damage. Measurements before and after cleaning showed a recoverable degradation due to dirt accumulation. This recoverable loss in power was 11 percent after 245 days in the field for one brand of module, 6 percent after 48 days for another brand, and 4 1/2 percent for the third brand. Author

**N77-27494\*** National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio.

**POTENTIAL BENEFITS OF A CERAMIC THERMAL BARRIER COATING ON LARGE POWER GENERATION GAS TURBINE**

John S. Clark and Joseph J. Nainiger Jun. 1977 57 p refs (Contract E(49-26)-1028) (NASA-TM-73712; E-9251; ERDA/NASA-5022/77/1) Avail: NTIS HC A04/MF A01 CSCL 10B

Thermal barrier coating design option offers benefit in terms of reduced electricity costs when used in utility gas turbines. Options considered include: increased firing temperature, increased component life, reduced cooling air requirements, and increased corrosion resistance (resulting in increased tolerance for dirty fuels). Performance and cost data were obtained. Simple, recuperated and combined cycle applications were considered, and distillate and residual fuels were assumed. The results indicate that thermal barrier coatings could produce large electricity cost savings if these coatings permit turbine operation with residual fuels at distillate-rated firing temperatures. The results also show that increased turbine inlet temperature can result in substantial savings in fuel and capital costs. Author

**N77-27497\*** National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio.

**PHOTOVOLTAIC-POWERED REFRIGERATOR EXPERIMENT AT ISLE ROYALE NATIONAL PARK**

A. F. Ratajczak Jun. 1977 32 p (Contract E(49-26)-1022) (NASA-TM-73703; E-9241; ERDA/NASA-1022/77/15) Avail: NTIS HC A03/MF A01 CSCL 10A

The use of a photovoltaic power system to operate an electric refrigerator at a trail construction camp at Isle Royale, Michigan is investigated. The use of P/V power for refrigeration in a remote installation is demonstrated. System design as well as predicted and measured system performance are presented. Author

**N77-28587\*** National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio.

**POLYMERIC MEMBRANE SYSTEMS OF POTENTIAL USE FOR BATTERY SEPARATORS**

Warren H. Philipp Washington Jul. 1977 15 p refs (NASA-TM-X-3567; E-9092) Avail: NTIS HC A02/MF A01 CSCL 10A

Two membrane systems were investigated that may have potential use as alkaline battery separators. One system comprises two miscible polymers: a support polymer (e.g., polyvinyl formal) and an ion conductor such as polyacrylic acid. The other system

involves a film composed of two immiscible polymers: a conducting polymer (e.g., calcium polyacrylate) suspended in an inert polymer support matrix, polyphenylene oxide. Resistivities in 45-percent potassium hydroxide and qualitative mechanical properties are presented for films comprising various proportions of conducting and support polymers. In terms of these parameters, the results are encouraging for optimum ratios of conducting to support polymers.

Author

**N77-28588\*** National Aeronautics and Space Administration, Lewis Research Center, Cleveland, Ohio.

**RELATION OF MORPHOLOGY OF ELECTRODEPOSITED ZINC TO ION CONCENTRATION PROFILE**

Charles E. May, Harold E. Kautz, and Brian B. Sabo Washington Jul. 1977 34 p refs

(NASA-TN-D-8527; E-9079) Avail: NTIS HC A03/MF A01 CSCL 10C

The morphology of electrodeposited zinc was studied with special attention to the ion concentration profile. The initial concentrations were 9M hydroxide ion and 1.21M zincate. Current densities were 6.4 to 64 mA/sq cm. Experiments were run with a horizontal cathode which was observed in situ using a microscope. The morphology of the zinc deposit was found to be a function of time as well as current density; roughly, the log of the transition time from mossy to large crystalline deposit is inversely proportional to current density. Probe electrodes indicated that the electrolyte in the cathode chamber was mixed by self induced convection. However, relatively large concentration gradients of the involved species existed across the boundary layer of the cathode. Analysis of the data suggests that the morphology converts from mossy to large crystalline when the hydroxide activity on the cathode surface exceeds about 12 M. Other experiments show that the pulse discharge technique had no effect on the morphology in the system where the bulk concentration of the electrolyte was kept homogeneous via self induced convection.

Author

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**TERRESTRIAL PHOTOVOLTAIC MEASUREMENT PROCEDURES**

Jun. 1977 18 p refs  
(Contract E(49-26)-1022)

(NASA-TM-73702; ERDA/NASA-1022-77/16; E-8421-1) Avail: NTIS HC A02/MF A01 CSCL 10A

Procedures for obtaining cell and array current-voltage measurements both outdoors in natural sunlight and indoors in simulated sunlight are presented. A description of the necessary apparatus and equipment is given for the calibration and use of reference solar cells. Some comments relating to concentration cell measurements, and a revised terrestrial solar spectrum for use in theoretical calculations, are included.

Author

**N77-29807\*** National Aeronautics and Space Administration, Lewis Research Center, Cleveland, Ohio.

**ANALYSIS OF REGENERATED SINGLE-SHAFT CERAMIC GAS-TURBINE ENGINES AND RESULTING FUEL ECONOMY IN A COMPACT CAR**

John L. Klann and Roy C. Tew, Jr. Washington Aug. 1977 23 p refs

(NASA-TM-X-3531; E-9103) Avail: NTIS HC A02/MF A01 CSCL 10B

Ranges in design and off-design operating conditions of an advanced gas turbine and their effects on fuel economy were analyzed. The assumed engine incorporated a single stage radial flow turbine and compressor with fixed geometry. Fuel economies were calculated over the composite driving cycle with gasoline as the fuel. At a constant turbine-inlet temperature, with a regenerator sized for a full power effectiveness the best fuel economy ranged from 11.1 to 10.2 km/liter (26.2 to 22.5 mpg) for full power turbine tip speeds of 770 to 488m/sec (2530 to 1800ft/sec), respectively.

Author

**N77-30698\*** National Aeronautics and Space Administration, Lewis Research Center, Cleveland, Ohio.

**EVALUATION OF PHASE 2 CONCEPTUAL DESIGNS AND IMPLEMENTATION ASSESSMENT RESULTING FROM THE ENERGY CONVERSION ALTERNATIVES STUDY (ECAS)**

Apr. 1977 605 p refs

(Contract E(49-18)-1751)

(NASA-TM-73515; E-8596) Avail: NTIS HC A99/MF A01 CSCL 10B

Advanced systems using coal and coal-derived fuels for base-load electric power generation were compared. The study was conducted in two phases. Phase 1 consisted of a parametric analysis. From these results, 11 concepts were selected for further study in Phase 2. For each of the Phase 2 systems and a common set of ground rules, the performance, cost, environmental intrusion, and natural resource requirements were estimated. In addition, the contractors defined the state of technology, identified advances required, and prepared preliminary research and development plans and an implementation assessment. The systems studied in Phase 2 include steam systems with atmospheric and pressurized-fluidized-bed boilers combined gas turbine/steam systems with integrated gasifiers or fired by a semiclean, coal-derived fuel; a potassium/steam system with a pressurized-fluidized-bed boiler; a closed-cycle gas turbine/organic system with a high-temperature, atmospheric-fluidized-bed furnace; a direct-coal-fired, open-cycle magnetohydrodynamic/steam system; and a molten carbonate fuel cell/steam system with integrated gasifier. The Phase 2 results are summarized and compared and presented together with NASA analysis and evaluation. The common ground rules specified for the study are presented. The sensitivity of the results to changes in the ground rules and the impact of uncertainties in capital cost estimates are examined.

Author

**N77-30599\*** National Aeronautics and Space Administration, Lewis Research Center, Cleveland, Ohio.

**DYNAMIC BLADE LOADING IN THE ERDA/NASA 100 kW AND 200 kW WIND TURBINES**

D. A. Spora, D. C. Janetzke, and T. R. Richards Aug. 1977 16 p refs Presented at the Natl Conf. of the Am Wind Energy Assoc., Boulder, Colo., 11-14 May 1977

(Contract E(49-26)-1004)

(NASA-TM-73711; ERDA/NASA-1004-77/2; E-9242) Avail: NTIS HC A02/MF A01 CSCL 10A

Dynamic blade loads, including aerodynamic, gravitational, and inertial effects, are presented for two large horizontal-axis wind turbines: the ERDA-NASA 100 kW Mod-0 and 200 kW Mod-0A wind power systems. Calculated and measured loads are compared for an experimental Mod-0 machine in operation. Predicted blade loads are also given for the higher power Mod-0A wind turbine now being assembled for operation as part of a municipal power plant. Two major structural modifications have been made to the Mod-0 wind turbine for the purpose of reducing blade loads. A stairway within the truss tower was removed to reduce the impulsive aerodynamic loading caused by the tower wake on the downwind rotor blades. Also, the torsional stiffness of the yaw drive mechanism connecting the turbine nacelle to the tower was doubled to reduce rotor-tower interaction loads. Measured reductions in load obtained by means of these two modifications equaled or exceeded predictions.

Author

**N77-30611\*** National Aeronautics and Space Administration, Lewis Research Center, Cleveland, Ohio.

**DRIVE TRAIN NORMAL MODES ANALYSIS FOR THE ERDA/NASA 100-KILOWATT WIND TURBINE GENERATOR**

T. L. Sullivan, D. R. Miller, and D. A. Spora Jul. 1977 34 p refs

(Contract E(49-26)-1028)

(NASA-TM-73718; E-9266; ERDA/NASA-1028-77/1) Avail: NTIS HC A03/MF A01 CSCL 10B

Natural frequencies, as a function of power were determined using a finite element model. Operating conditions investigated were operation with a resistive electrical load and operation synchronized to an electrical utility grid. The influence of certain drive train components on frequencies and mode shapes is shown.

An approximate method for obtaining drive train natural frequencies is presented  
Author

**N77-31801\*** National Aeronautics and Space Administration  
Lewis Research Center, Cleveland, Ohio  
**SOLAR CELL SHINGLE Patent**  
Americo F. Forestieri, Anthony F. Ratajczak, and Leroy G. Sidorak,  
inventors (to NASA) Issued 9 Aug. 1977 5 p. Filed 24 Aug.  
1976 Supersedes N77-10845 (15 - 01, p. 0091)  
(NASA-Case-LEW-12587-1; US-Patent-4,040,867;  
US-Patent-Appl-SN-717319; US-Patent-Class-136-89P;  
US-Patent-Class-52-173; RUS-Patent-Class-52-518;  
US-Patent-Class-136-89-AC) Avail: US Patent Office CSCL  
10A

A solar cell shingle was made of an array of solar cells on a lower portion of a substantially rectangular shingle substrate made of fiberglass cloth or the like. The solar cells may be encapsulated in fluorinated ethylene propylene or some other weatherproof translucent or transparent encapsulant to form a combined electrical module and a roof shingle. The interconnected solar cells were connected to connectors at the edge of the substrate through a connection to a common electrical bus or busses. An overlap area was arranged to receive the overlap of a cooperating similar shingle so that the cell portion of the cooperating shingle may overlie the overlap area of the roof shingle. Accordingly, the same shingle serves the double function of an ordinary roof shingle which may be applied in the usual way and an array of cooperating solar cells from which electrical energy may be collected.

Official Gazette of the U.S. Patent Office

**N77-31812\*** National Aeronautics and Space Administration,  
Lewis Research Center, Cleveland, Ohio.  
**NASA THERMIONIC CONVERSION PROGRAM**  
James F. Morris 1977 9 p. refs. Presented at the 12th  
Intersoc. Energy Conversion Eng. Conf., Washington, D.C.,  
28 Aug. - 2 Sep. 1977; cosponsored by the IEEE, the Am.  
Inst. of Chem. Eng., the Am. Nucl. Soc., the Soc. of Automotive  
Eng., the Am. Chem. Soc., the AIAA, and the ASME  
(NASA-TM-X-73844; E-9150) Avail: NTIS HC A02/MF A01  
CSCL 10A

Technological processes in out-of-core thermionic energy conversion are described. The emphasis was on high temperature electrode materials and system engineering of converter geometries to produce practical power densities. I.M.

**N77-31614\*** National Aeronautics and Space Administration,  
Lewis Research Center, Cleveland, Ohio.  
**INVESTIGATION OF EXCITATION CONTROL FOR WIND-  
TURBINE GENERATOR STABILITY**  
Vernon D. Gebben Aug 1977 16 p. refs.  
(NASA-TM-73745; E-9313; ERDA/NASA/1028-77/3) Avail:  
NTIS HC A02/MF A01 CSCL 10B

High speed horizontal axis wind turbine generators with blades on the downwind side of the support tower require special design considerations to handle disturbances introduced by the flow wake behind the tower. Experiments and analytical analyses were made to determine benefits that might be obtained by using the generator exciter to provide system damping for reducing power fluctuations. Author

**N77-32585\*** National Aeronautics and Space Administration,  
Lewis Research Center, Cleveland, Ohio.  
**CESIUM THERMIONIC CONVERTERS HAVING LANTHANUM  
HEXABORIDE ELECTRODES Patent Application**  
James F. Morris, inventor (to NASA) Filed 24 Nov. 1976 8 p.  
(NASA-Case-LEW-12038-2; US-Patent-Appl-SN-744576) Avail:  
NTIS HC A02/MF A01 CSCL 10A

A high electric-power output thermionic converter is provided for by the combination of lanthanum hexaboride emitter and collector electrodes in a cesium thermionic converter. The interaction between the lanthanum hexaboride electrodes and

cesium vapor which is adsorbed on the lanthanum hexaboride electrodes results in lower emitter and collector work functions to produce a thermionic converter having a high current density and voltage output. The lanthanum hexaboride emitter and collector electrodes in the cesium thermionic converter may be employed in either the monocrystalline or polycrystalline state. NASA

**A77-21787\*** An investigation of impurity redistribution in diffused layer on  $n^+p$  silicon solar cells parameters. E. Y. Wang, I. Hsu (Wayne State University, Detroit, Mich.), and H. W. Brandhorst, Jr. (NASA, Lewis Research Center, Cleveland, Ohio). In: International Conference on Solar Electricity, Toulouse, France, March 1-5, 1976, Reports. (A77-21776 08-44) Toulouse, Centre National d'Etudes Spatiales, 1976, p. 169-181, 8 refs.

Recent calculations by Wang et al. (1974) have shown that the short circuit current for silicon solar cells is sensitive to the impurity distribution in the diffused and base region. In the present work, these theoretical results were verified by experimentally investigating the impurity profile and sheet resistance of the diffused layers of  $n^+p$  silicon solar cells fabricated by normal diffusion processes and at subsequently various drive-in times. Impurity profiles of the  $n^+$  diffused layer, measured by differential Hall and resistivity technique, resemble the etc distribution. The junction depth is larger as drive-in time increases. Measured short-circuit current is in agreement with calculated ones. Open-circuit voltage is independent of drive-in times, and its calculated values are consistent with capacitance voltage measurements. P.T.H.

**A77-21838\*** Photovoltaic test and demonstration project. A. F. Forestieri, H. W. Brandhorst, Jr., and J. N. Deyo (NASA, Lewis Research Center, Cleveland, Ohio). In: International Conference on Solar Electricity, Toulouse, France, March 1-5, 1976, Reports. (A77-21776 08-44) Toulouse, Centre National d'Etudes Spatiales, 1976, p. 765-769.

The considered project consists of three subprojects related to applications, device performance and diagnostics, and endurance testing. The objectives of the applications subproject include the determination of the operating characteristics for a variety of photovoltaic conversion systems. A system test facility is being constructed in this connection and a prototype residence experiment is to be conducted. Market demand for solar cells is to be stimulated by demonstrating suitability of solar cells for specific near term applications. Activities conducted in connection with device performance studies and diagnostics are also discussed along with developments in the area of endurance testing. G.R.

**A77-23390\*** Clean fuels from biomass. Y. Y. Hsu (NASA, Lewis Research Center, Cleveland, Ohio). *Energy Quarterly*, vol. 6, Jan. 1, 1976, p. 6-19, 19 refs.

The paper discusses the U.S. resources to provide fuels from agricultural products, the present status of conversion technology of clean fuels from biomass, and a system study directed to determine the energy budget, and environmental and socioeconomic impacts. Conversion processes are discussed relative to pyrolysis and anaerobic fermentation. Pyrolysis breaks the cellulose molecules to smaller molecules under high temperature in the absence of oxygen, whereas anaerobic fermentation is used to convert biomass to methane by means of bacteria. Cost optimization and energy utilization are also discussed. S.D.

**A77-26392\*** Status of silicon solar cell technology. F. W. Brandhorst, Jr. (NASA, Lewis Research Center, Cleveland, Ohio). *Japan Society of Applied Physics, International Conference on Solid State Devices*, 2nd, Tokyo, Japan, Sept. 1-3, 1976, Pt. 1, p. 17 p. 18 refs.

It is pointed out that during the time from 1970 to 1976 the

efficiency of solar cells has increased from 17.5 to 15.5%. Most of the increased output has resulted from increased short circuit current. Advances leading to this improvement in performance are discussed, taking into account a reduction in the area covered by the grid pattern, the use of antireflection coatings, and the employment of surface texturizing. A widespread use of solar cells for nonspace applications requires a reduction in the cost of solar cell arrays from the present \$20 per watt to 10 to 50 cents per watt. Approaches for achieving this objective are considered. Attention is given to an automated, high volume production of solar cells made from ribbon silicon or thin film layers.

G.R.

**A77-30716 \*** A first order theory of the p(+)-n-n(+) edge-illuminated silicon solar cell at very high injection levels. C. Goradia (Cleveland State University, Cleveland, Ohio) and B. L. Sater (NASA, Lewis Research Center, Cleveland, Ohio). *IEEE Transactions on Electron Devices*, vol. ED-24, Apr. 1977, p. 342-351. 20 refs.

A first order theory of the edge-illuminated p(+)-n-n(+) silicon solar cell under very high injection levels has been derived. The very high injection level illuminated J-V characteristic is derived for any general base width to diffusion length (W/L) ratio and it includes the minority carrier reflection by the n-n(+) high-low junction. The beneficial effects of the high-low junction are shown to be significant until extremely high injection levels are reached. The theoretical dependencies of  $J_{sc}$  and  $V_{oc}$  on temperature, incident intensity, and base resistivity are derived and discussed in detail. Some experimental results are given and these are discussed in relation to the theory.

(Author)

**A77-30725 \*** A methodology for experimentally based determination of gap shrinkage and effective lifetimes in the emitter and base of p-n junction solar cells and other p-n junction devices. F. A. Lindholm, A. Neugroschel (Florida University, Gainesville, Fla.), C. T. Sah (Illinois University, Urbana, Ill.), M. P. Godlewski, and H. W. Brandhorst, Jr. (NASA, Lewis Research Center, Cleveland, Ohio). *IEEE Transactions on Electron Devices*, vol. ED-24, Apr. 1977, p. 402-410. 26 refs. Grant No. NSG-3018; Contract No. E(40-1)-5134.

An experimentally based methodology that determines the effective gap shrinkage and lifetime in the emitter of a p-n junction solar cell is described which provides an experimental means for assessing the importance of gap shrinkage relative to that of large recombination rates in the highly doped emitter. The base lifetime is also determined. The methodology pertains to a solar cell after the junction is formed, so that each material parameter determined includes the effects of the processing used in junction fabrication. The methodology consists of strategy and procedures for designing experiments and interpreting data consistently with the physical mechanisms governing device behavior. This careful linking to the device physics uncover the material parameters concealed in the data. To illustrate the procedures, they are applied to an n(+)-p solar cell having substrate resistivity of about 0.1 ohm-cm.

(Author)

P. I. H.

**A77-32242 \*** Application of the SEM to the measurement of solar cell parameters. V. G. Weizer and C. W. Andrews (NASA, Lewis Research Center, Cleveland, Ohio). *Illinois Institute of Technology, Annual Scanning Electron Microscopy Symposium*, 10th, Chicago, Ill., Mar. 28-Apr. 1, 1977, Paper. 7, p. 21 refs.

A pair of techniques are described which make use of the SEM to measure, respectively, the minority carrier diffusion length and the metallurgical junction depth in silicon solar cells. The former technique permits the measurement of the true bulk diffusion length through the application of highly doped  $n^+$  layers to the back surfaces of the cells being investigated. The technique yields an absolute value of the diffusion length from a knowledge of the collected fraction of the injected carriers and the cell thickness. It is shown that the secondary emission contrast observed in the SEM on a reverse-biased diode can depict the location of the metallurgical

junction if the diode has been prepared with the proper beveled geometry. The SEM provides the required contrast and the option of high magnification, permitting the measurement of extremely shallow junction depths.

(Author)

**A77-32243 \*** Synchronization of the ERDA-NASA 100 kW wind turbine generator with large utility networks. H. H. Hwang (Hawaii University, Honolulu, Hawaii) and L. J. Gilbert (NASA, Lewis Research Center, Cleveland, Ohio). *Institute of Electrical and Electronics Engineers, Control of Power Systems Conference and Exposition, College Station, Tex., Mar. 14-16, 1977, Paper*. 16 p. 5 refs. Research supported by the Hawaiian Natural Energy Institute and NASA.

The synchronizing of a wind turbine generator against an infinite bus under random conditions is studied for the first time. With a digital computer, complete solutions for rotor speed, generator power angle, electromagnetic torque, wind turbine torque, wind turbine blade pitch angle, and armature current are obtained and presented by graphs. Experiments have been recently performed on the ERDA-NASA 100 kW wind turbine. Experimental results matched computer study results very closely and confirmed that the synchronization can be accomplished by means of the existing speed control system and an automatic synchronizer.

(Author)

**A77-33405 \*** Energy storage possibilities of atomic hydrogen. R. D. Etters (Colorado State University, Fort Collins, Colo.), J. V. Dugan, Jr. (U.S. Congress, Science and Technology Committee, Washington, D.C.), and R. Palmer (NASA, Lewis Research Center, Cleveland, Ohio). In: *World Hydrogen Energy Conference*, 1st, Miami Beach, Fla., March 1-3, 1976, Proceedings, Volume 3. (A77-33326 14-44) Coral Gables, Fla., University of Miami; New York, Pergamon Press, 1976, p. 9C-3 to 9C-20. 13 refs. Grant No. NGL-06-002-159.

The possibility of storing large amounts of energy in a free radical system such as atomic hydrogen is analyzed. Attention is focused on theoretical calculations of the ground state properties of

spin-aligned atomic triplet hydrogen, deuterium, and tritium. The solid-liquid phase transition in atomic hydrogen is also examined.

S.D.

**A77-38224 \*** Experimental solar heating-cooling system model tests of a full-scale building system. D. Namkoong (NASA, Lewis Research Center, Cleveland, Ohio). In: *Modeling and simulation. Volume 7 - Proceedings of the Seventh Annual Pittsburgh Conference*, Pittsburgh, Pa., April 26, 27, 1976, Part 2. (A77-38176 17-66) Pittsburgh, Pa., Instrument Society of America, 1976, p. 1103-1113. 10 refs.

An experimental solar heating and cooling system model has been built and operated, combining elements that are programmable - heating and/or cooling load of a building, collected solar energy - with experimental equipment. The system model was based on the loads and components used in the Solar Building Test Facility (SBTF) which includes a 1394 square meter solar collector field, at NASA-Langley. Operations covered 5 continuous days under summer conditions. For the system model, up to 55% of the simulated collected solar energy was used for the building load. This amount constituted 35% of the building cooling load. Heat loss was significant. If tank heat loss were eliminated, 75% of the collected solar energy would be used. This amount would supply approximately 50% of the building cooling load.

(Author)

**A77-41556 \*** Thermal storage for electric utilities. C. J. Sweet (ERDA, Washington, D.C.) and W. J. Masica (NASA, Lewis Research Center, Cleveland, Ohio). In: *New options in energy technology; Proceedings of the Conference*, San Francisco, Calif., August 24, 1977. (A77-41551 19-44) New York, American Institute of Aeronautics and Astronautics, Inc., 1977, p. 26-32. 17 refs.



(AIAA 77-1009)

Applications of the thermal energy storage (TES) principle (storage of sensible heat or latent heat, or heat storage in reversible chemical reactions) in power systems are evaluated. Load leveling behind the meter, load following at conventional thermal power plants, solar thermal power generation, and waste heat utilization are the principal TES applications considered. Specific TES examples discussed include: storage heaters for electric-resistance space heating, air conditioning TES in the form of chilled water or eutectic salt baths, hot water TES, and trans-seasonal storage in heated water in confined aquifers.

R.D.V.

**A77-47960 \*** The NASA thermionic-conversion /TEC-ART/ program. J. F. Morris (NASA, Lewis Research Center, Thermionics and Heat-Pipe Section, Cleveland, Ohio). *Institute of Electrical and Electronics Engineers, Conference on Plasma Science, Troy, N.Y., May 23-25, 1977, Paper. 18 p. 11 refs.*

The NASA program for applied research and technology in thermionic energy conversion is described, and the approaches used to obtain the goal of reduced interelectrode losses, improved emitters, and improved collectors are indicated. The current emphasis on out-of-core thermionics allows materials and designs previously prohibited by in-core nucleonics and geometries. Since high-temperature material effects are important for several components, tungsten, 25%-rhenium technology is a subject of research. Emitter-vaporization, collector-deposition effects were studied, and improvements in metallic-fluid heat pipes are considered. Some required characteristics of electrodes are examined.

M. .

**A77-48765 \*** Molten salt thermal energy storage for utility peaking loads. A. Ferrara, R. Haslett (Grumman Aerospace Corp., Bethpage, N.Y.), and J. Joyce (NASA, Lewis Research Center, Cleveland, Ohio). *In: Intersociety Energy Conversion Engineering Conference, 12th, Washington, D.C., August 28-September 2, 1977, Proceedings, Volume 1. (A77-48701 23-44) La Grange Park, Ill., American Nuclear Society, Inc., 1977, p. 547-554. 6 refs.*

This paper considers the use of thermal energy storage (TES) in molten salts to increase the capacity of power plants. Five existing fossil and nuclear electric utility plants were selected as representative of current technology. A review of system load diagrams indicated that TES to meet loads over 95% of peak was a reasonable goal. Alternate TES heat exchanger locations were evaluated, showing that the stored energy should be used either for feedwater heating or to generate steam for an auxiliary power cycle. Specific salts for each concept are recommended. Design layouts were prepared for one plant, and it was shown that a TES tube/shell heat exchanger system could provide about 7% peaking capability at lower cost than adding steam generation capacity. Promising alternate heat exchanger concepts were also identified.

(Author)

**A77-48886 \*** NASA Thermionic-Conversion program. J. F. Morris (NASA, Lewis Research Center, Thermionics and Heat-Pipe Section, Cleveland, Ohio). *In: Intersociety Energy Conversion Engineering Conference, 12th, Washington, D.C., August 28-September 2, 1977, Proceedings, Volume 2. (A77-48701 23-44) La Grange Park, Ill., American Nuclear Society, Inc., 1977, p. 1540-1547. 14 refs.*

NASA's program for applied research and technology (ART) in Thermionic Energy Conversion (TEC) has made worthwhile contributions in a relatively short time. Materials and designs previously prohibited by in-core nucleonics and geometries now offer new potentialities. High-temperature material effects are crucial to the level and duration of TEC performance. New electrodes must increase and maintain power output regardless of emitter-vapor deposition on collectors. They must also serve compatibly with hot-shell alloys. And while space TEC must face high-temperature vaporization problems externally as well as internally, terrestrial TEC

must tolerate hot corrosive atmospheres outside and near-vacuum inside. Furthermore, some modes for decreasing interelectrode losses appear to require rather demanding converter geometries to produce practical power densities.

(Author)

**A77-49160 \*** Fundamental studies of black chrome for solar collector use. G. McDonald, B. Buzek, and H. Curtis (NASA, Lewis Research Center, Cleveland, Ohio). *International Solar Energy Society and Solar Energy Society of Canada, Joint Conference on Sharing the Sun: Solar Technology in the Seventies, Winnipeg, Canada, Aug. 15-20, 1976, Paper. 4 p.*

The thicknesses of black chrome plated for various times have been measured from electron photomicrographs and correlated with the solar spectrum absorptance and infrared emittance as calculated from spectral reflectance measurements. The maximum absorptance is reached at an average thickness of 0.5 micrometer. The emittance increases only slightly up to 1.0 micrometer but increases rapidly at thickness above 1.0 micrometer.

(Author)

**A77-49161 \*** Evaluation of flat-plate collector efficiency under controlled conditions in a solar simulator. S. M. Johnson and F. F. Simon (NASA, Lewis Research Center, Cleveland, Ohio). *International Solar Energy Society and Solar Energy Society of Canada, Joint Conference on Sharing the Sun: Solar Technology in the Seventies, Winnipeg, Canada, Aug. 15-20, 1976, Paper. 19 p. 9 refs.*

The measured thermal efficiencies of 35 collectors tested with a solar simulator, along with the correlation equations used to generalize the data, are presented in this report. The single correlation used is shown to apply to all the different types of collectors tested, including one with black paint and one cover, one with a selective surface coating and two covers, and an evacuated-tube collector. The test and correlation technique is also modified by using a shield so that collectors larger than the simulator test area can also be tested. This technique was verified experimentally for a shielded collector for which the collector shielded area was 31% of the solar simulator radiation area. A table lists all the collectors tested, the collector areas, and the experimental constants used to correlate the data for each collector.

(Author)

**A77-49162 \*** Performance correlations of five solar collectors tested simultaneously outdoors. D. R. Miller (NASA, Lewis Research Center, Cleveland, Ohio). *International Solar Energy Society and Solar Energy Society of Canada, Joint Conference on Sharing the Sun: Solar Technology in the Seventies, Winnipeg, Canada, Aug. 15-20, 1976, Paper. 26 p.*

Collector thermal efficiency, and efficiency degradation with time were measured for 5 flat-plate solar collectors tested simultaneously in an outdoor solar collector test facility. Results indicate that by using collector performance parameters which account for diffuse insolation, outdoor data recorded on 'cloudy' days can be used as a measure of performance, as long as the ratio of direct to total insolation exceeds approximately 0.6. These outdoor results also show good agreement with thermal efficiency data obtained indoors in a solar simulator. Significant efficiency degradation occurred on only one of the five collectors exposed to outdoor conditions for a period of one to two years.

(Author)

**A77-49163 \*** An experimental investigation with artificial sunlight of a solar hot-water heater. F. F. Simon (NASA, Lewis Research Center, Cleveland, Ohio). *International Solar Energy Society and Solar Energy Society of Canada, Joint Conference on Sharing the Sun: Solar Technology in the Seventies, Winnipeg, Canada, Aug. 15-20, 1976, Paper. 19 p. 8 refs.*

Thermal performance measurements were made of a commercial solar hot-water heater in a solar simulator. The objective of the test was to determine basic performance characteristics of a traditional



type of flat-plate collector, with and without side reflectors (to increase the solar flux). Due to the fact that collector testing in the solar simulator permits control of the variables that affect collector performance, it was possible to obtain information on each of the following: (1) the effect of flow and incidence angle on the efficiency of a flat-plate collector (but only without side reflectors), (2) transient performance under flow and nonflow conditions, (3) the effectiveness of reflectors in increasing collector efficiency for a zero radiation angle at fluid temperatures required for solar air conditioning, and (4) the limits of applicability of a collector efficiency correlation based on the Hottel-Whillier equation (1958). (Author)

**A77-49164 \*** Initial operation of a solar heating and cooling system in a full-scale solar building test facility. R. H. Knoll, D. Miao (NASA, Lewis Research Center, Cleveland, Ohio), I. L. Hamlet, and R. N. Jensen (NASA, Langley Research Center, Hampton, Va.). *International Solar Energy Society and Solar Energy Society of Canada, Joint Conference on Sharing the Sun: Solar Technology in the Seventies, Winnipeg, Canada, Aug. 15-20, 1976, Paper, 17 p.*

The Solar Building Test Facility (SBTF) located at Hampton, Virginia became operational in early summer of 1976. This facility is a joint effort by NASA-Lewis and NASA-Langley to advance the technology for heating and cooling of office buildings with solar energy. Its purposes are to (1) test system components which include high-performing collectors, (2) test performance of complete solar heating and cooling system, (3) investigate component interactions and (4) investigate durability, maintenance and reliability of components. The SBTF consists of a 50,000 square foot office building modified to accept solar heated water for operation of an absorption air conditioner and for the baseboard heating system. A 12,666 square foot solar collector field with a 30,000 gallon storage tank provides the solar heated water. A description of the system and the collectors selected is given here, along with the objectives, test approach, expected system performance and some preliminary results. (Author)

**A77-49165 \*** Measured performance of a 3-ton LiBr absorption water chiller and its effect on cooling system operation. D. Namkoong (NASA, Lewis Research Center, Cleveland, Ohio). *International Solar Energy Society and Solar Energy Society of Canada, Joint Conference on Sharing the Sun: Solar Technology in the Seventies, Winnipeg, Canada, Aug. 15-20, 1976, Paper, 10 p. 8 refs.*

A 3-ton lithium bromide absorption water chiller was tested for a number of conditions involving hot-water input, chilled water, and the cooling water. The primary influences on chiller capacity were the hot water inlet temperature and the cooling water inlet temperature. One combination of these two parameters extended the output to as much as 125% of design capacity, but no combination could lower the capacity to below 60% of design. A cooling system was conceptually designed so that it could provide several modes of operation. Such flexibility is needed for any solar cooling system to be able to accommodate the varying solar energy collection and the varying building demand. It is concluded that a 3-ton absorption water chiller with the kind of performance that was measured can be incorporated into a cooling system such as that proposed, to provide efficient cooling over the specified ranges of operating conditions. (Author)

**N77-10639\*** Yardney Electric Corp., Pawcatuck, Conn. Electric Div. **EVALUATION OF INORGANIC/ORGANIC SEPARATORS** Final Report

C. Philip Donnel, III Oct. 1976 20 p  
(Contract NAS3-18530)  
(NASA-CR-135108) Avail. NTIS HC A02/MF A01 CSCL 10C

Thirty-six (36) experimental 40AH sealed silver-zinc cells were constructed during phase I of this two (2) phase program. These cells were divided into six (6) groups of six (6) cells each. Each

group of six (6) cells was evenly divided into two batches of three (3) cells each. Groups 1 through 4 each featured a different inorganic filler material in the slurry used to coat the separator substrate. Groups 5 and 6 featured an alternate method of separator bag construction. With the exception of the various separator materials, the parts and processes used to produce these thirty-six (36) cells were the same as those used to make the HR40-7 cell. The two (2) batches of cells in each cell group differed only in the lots of solutions and other separator slurry components used. Each cell was given two formation charge/discharge cycles prior to being shipped to NASA Lewis Research Center. Phase II of the program consisted of constructing another thirty-six (36) 40AH experimental cells in six (6) groups of six (6) cells each. Each group was distinguished by the type of precoated separator material used to fabricate separator bags. A new method of separator bag construction was used in this phase of the program. These cells were given two (2) formation cycles and shipped to NASA Lewis Research Center. Author

**N77-11531\*** TRW Defense and Space Systems Group, Redondo Beach Calif.

**FLEXIBLE, FEP-TEFLON COVERED SOLAR CELL MODULE DEVELOPMENT** Final Report

H. S. Rauschenbach and M. D. Cannady 13 Oct 1976 158 p refs

(Contract NAS3-16742)

(NASA-CR-135109; TR-22353-6001-RU-00) Avail. NTIS HC A08/MF A01 CSCL 10A

Techniques and equipment were developed for the large scale, low-cost fabrication of lightweight, roll-up and fold-up, FEP-Teflon encapsulated solar cell modules. Modules were fabricated by interconnecting solderless single-crystal silicon solar cells and heat laminating them at approximately 300 C between layers of optically clear FEP and to a loadbearing Kapton substrate sheet. Modules were fabricated from both conventional and wraparound contact solar cells. A heat seal technique was developed for mechanically interconnecting modules into an array. The electrical interconnections for both roll-up and fold-up arrays were also developed. The use of parallel-gap resistance welding, ultrasonic bonding, and thermocompression bonding processes for attaching interconnects to solar cells were investigated. Parallel-gap welding was found to be best suited for interconnecting the solderless solar cells into modules. Details of the fabrication equipment, fabrication processes, module and interconnect designs, environmental test equipment, and test results are presented. Author

**N77-12510\*** Dynatech R/D Co., Cambridge, Mass. **THERMAL ENERGY STORAGE MATERIAL THERMOPHYSICAL PROPERTY MEASUREMENT AND HEAT TRANSFER IMPACT**

R. P. Tye, J. G. Bourne, and A. O. Destarlais 11 Aug. 1976 98 p refs

(Contract NAS3-19716)

(NASA-CR-135098; Rept-1503) Avail. NTIS HC A05/MF A01 CSCL 10A

The thermophysical properties of salts having potential for thermal energy storage to provide peaking energy in conventional electric utility power plants were investigated. The power plants studied were the pressurized water reactor, boiling water reactor, supercritical steam reactor, and high temperature gas reactor. The salts considered were  $\text{LiNO}_3$ ,  $63\text{LiOH}/37\text{LiCl}$  eutectic,  $\text{LiOH}$ , and  $\text{Na}_2\text{B}_4\text{O}_7$ . The thermal conductivity, specific heat (including latent heat of fusion), and density of each salt were measured for a temperature range of at least  $\pm 100$  K of the measured melting point. Measurements were made with both reagent and commercial grades of each salt. Author

**N77-13532\*** General Electric Co., Philadelphia, Pa. Space Div.

**DEFINITION STUDY FOR PHOTOVOLTAIC RESIDENTIAL**

**PROTOTYPE SYSTEM**

Neal F. Shepard, Ralph Landes, and William P. Kornumpf Sep. 1976 271 p refs

(Contract NAS3-19769)  
(NASA-CR-135039: Doc-76SDS4225) Avail: NTIS  
HC A12/MF A01 CSCL 10B

A site evaluation was performed to assess the relative merits of different regions of the country in terms of the suitability for experimental photovoltaic powered residences. Eight sites were selected based on evaluation criteria which included population, photovoltaic systems performance and the cost of electrical energy. A parametric sensitivity analysis was performed for four selected site locations. Analytical models were developed for four different power system implementation approaches. Using the model which represents a direct (or float) charge system implementation the performance sensitivity to the following parameter variations is reported: (1) solar roof slope angle; (2) ratio of the number of series cells in the solar array to the number of series cells in the lead-acid battery; and (3) battery size. For a Cleveland site location, a system with no on site energy storage and with a maximum power tracking inverter which feeds back excess power to the utility was shown to have 19 percent greater net system output than the second place system. The experiment test plan is described. The load control and data acquisition system and the data display panel for the residence are discussed. Author

**N77-13533\*** Martin Marietta Corp., Denver, Colo.  
**DEFINITION STUDY FOR PHOTOVOLTAIC RESIDENTIAL**  
**PROTOTYPE SYSTEM Final Report**

M. S. Imamura, R. Hulstrom, C. Cookson, B. H. Waldman (Brooks Waldman Assoc.), and R. Lane (Brooks Waldman Assoc.) Sep. 1976 303 p refs

(Contract NAS3-19768)  
(NASA-CR-135056: MCR-76-394: ERDA/NASA-19768) Avail:  
NTIS HC A14/MF A01 CSCL 10A

A parametric sensitivity study and definition of the conceptual design is presented. A computer program containing the solar irradiance, solar array, and energy balance models was developed to determine the sensitivities of solar insolation and the corresponding solar array output at five sites selected for this study as well as the performance of several solar array/battery systems. A baseline electrical configuration was chosen, and three design options were recommended. The study indicates that the most sensitive parameters are the solar insolation and the inverter efficiency. The baseline PST selected is comprised of a 133 sq m solar array, 250 ampere hour battery, one to three inverters, and a full shunt regulator to limit the upper solar array voltage. A minicomputer controlled system is recommended to provide the overall control, display, and data acquisition requirements. Architectural renderings of two photovoltaic residential concepts, one above ground and the other underground, are presented. The institutional problems were defined in the areas of legal liabilities during and after installation of the PST, labor practices, building restrictions and architectural guides, and land use. Author

**N77-15488\*** Spectrolab, Inc., Sylmar, Calif.  
**A PROGRAM CONTINUATION TO DEVELOP PROCESSING**  
**PROCEDURES FOR ADVANCED SILICON SOLAR CELLS**  
J. E. Avery and J. A. Scott-Monck Nov. 1976 43 p refs

(Contract NAS3-17350)  
(NASA-CR-135114) Avail: NTIS HC A03/MF A01 CSCL 10A

Shallow junctions, aluminum back surface fields and tantalum pentoxide (Ta<sub>2</sub>O<sub>5</sub>) antireflection coatings coupled with the development of a chromium-palladium-silver contact system, were used to produce a 2 x 4 cm wraparound contact silicon solar cell. One thousand cells were successfully fabricated using batch processing techniques. These cells were 0.020 mm thick, with the majority (800) made from nominal ten ohm-cm silicon and

the remainder from nominal 30 ohm-cm material. Unfiltered, these cells delivered a minimum AMO efficiency at 25 C of 11.5 percent and successfully passed all the normal in-process and acceptance tests required for space flight cells. Author

**N77-15492\*** Spectrolab, Inc., Sylmar, Calif.  
**DEMONSTRATION OF THE FEASIBILITY OF AUTOMATED**  
**SILICON SOLAR CELL FABRICATION Final Report**

J. Thornhill and W. E. Taylor Aug 1976 54 p

(Contract NAS3-19566)  
(NASA-CR-135095: Rept-3884-FR) Avail: NTIS  
HC A04/MF A01 CSCL 10A

An analysis of estimated costs indicate that for an annual output of 4,747,000 hexagonal cells (38 mm. on a side) a total factory cost of \$0.866 per cell could be achieved. For cells with 14% efficiency at AMO intensity (1353 watts per square meter), this annual production rate is equivalent to 3.373 kilowatts and a manufacturing cost of \$1.22 per watt of electrical output. A laboratory model of such a facility was operated to produce a series of demonstration runs, producing hexagonal cells, 2 x 2 cm cells and 2 x 4 cm cells. Author

**N77-17566\*** Owens-Illinois, Inc., Toledo, Ohio  
**THICK-FILM MATERIALS FOR SILICON PHOTOVOLTAIC**  
**CELL MANUFACTURE Final Report**

M. B. Field Jan. 1977 22 p

(Contract NAS3-19441)  
(NASA-CR-135134) Avail: NTIS HC A02/MF A01 CSCL 10A

Thick film technology is applicable to three areas of silicon solar cell fabrication, metallization, junction formation, and coating for protection of screened ohmic contacts, particularly wrap around contacts, interconnection and environmental protection. Both material and process parameters were investigated. Printed ohmic contacts on n- and p-type silicon are very sensitive to the processing parameters of firing time, temperature, and atmosphere. Wrap around contacts are easily achieved by first printing and firing a dielectric over the edge and subsequently applying a low firing temperature conductor. Interconnection of cells into arrays can be achieved by printing and cofiring thick film metal pastes, soldering, or with heat curing conductive epoxies on low cost substrates. Printed (thick) film vitreous protection coatings do not yet offer sufficient optical uniformity and transparency for use on silicon. A sprayed, heat curable SiO<sub>2</sub> based resin shows promise of providing both optical matching and environmental protection. Author

**N77-20558\*** Paragon Pacific, Inc., El Segundo, Calif.  
**COUPLED DYNAMICS ANALYSIS OF WIND ENERGY**  
**SYSTEMS Final Report**

John A. Hoffman Feb. 1977 86 p refs

(Contract NAS3-19767)  
(NASA-CR-135152: PPI-1014-11) Avail: NTIS  
HC A05/MF A01 CSCL 10A

A qualitative description of all key elements of a complete wind energy system computer analysis code is presented. The analysis system addresses the coupled dynamics characteristics of wind energy systems, including the interactions of the rotor, tower, nacelle, power train, control system, and electrical network. The coupled dynamics are analyzed in both the frequency and time domain to provide the basic motions and loads data required for design, performance verification and operations analysis activities. Elements of the coupled analysis code were used to design and analyze candidate rotor articulation concepts. Fundamental results and conclusions derived from these studies are presented. Author

**N77-21551\*** AiResearch Mfg. Co., Torrance, Calif.  
**BRAYTON-CYCLE HEAT EXCHANGER TECHNOLOGY**  
**PROGRAM Final Report**

J. J. Killackey, M. G. Coombs, R. F. Graves, and C. J. Morse Aug. 1976 365 p refs

(Contract NAS3-15347)

(NASA-CR-135158; AirResearch-75-12055) Avail: NTIS HC A16/MF A01 CSCL 10B

The following five tasks designed to advance this development of heat exchanger systems for close loop Brayton cycle power systems are presented: (1) heat transfer and pressure drop data for a finned tubular heat transfer matrix. The tubes are arranged in a triangular array with copper stainless steel laminate strips helically wound on the tubes to form a disk fin geometry; (2) the development of a modularized waste heat exchanger. Means to provide verified double containment are described; (3) the design, fabrication, and test of compact plate fin heat exchangers representative of full scale Brayton cycle recuperators; (4) the analysis and design of bellows suitable for operation at 1600 F and 200 psia for 1,000 cycles and 50,000 hours creep life; and (5) screening tests used to select a low cost braze alloy with the desirable attributes of a gold base alloy. A total of 22 different alloys were investigated; the final selection was Microbraz 30.

Author

**N77-21588\*** Kentucky Univ., Lexington. College of Engineering

**PROCESS SENSITIVITY STUDIES OF THE WESTINGHOUSE SULFUR CYCLE FOR HYDROGEN GENERATION**

R H. Carty, K E. Cox (New Mexico Univ., Albuquerque), J. E. Funk, M. A. Soliman (Riyadh Univ., Saudi Arabia), W. L. Conger, L. E. Brecher (Westinghouse Res. Labs., Pittsburgh), and S. Spewock (Westinghouse Res. Labs., Pittsburgh) In Miami Univ. First World Hydrogen Energy Conf. Proc., Vol. 1 Mar 1976 12 p refs (For primary document see N77-21552 12-44)

(Contract NAS3-18934)  
Avail: NTIS HC A99/MF A01

The effect of variations of acid concentration, pressure, and temperature on the thermal process efficiency of the Westinghouse sulfur cycle was examined using the HYDRGN program. Modifications to the original program were made to duplicate the process flowsheet and take into account combined cycle heat-to-work efficiencies for electrochemical work requirements, aqueous solutions, and heat-of-mixing effects. A total of 125 process variations were considered (acid concentration: 50-90 w/o; pressure: 15-750 psia; temperature: 922K - 1366K). The methods of analysis, results, and conclusions are presented.

Author

**N77-21589\*** Westinghouse Electric Corp., Pittsburgh, Pa.  
**HYDROGEN PRODUCTION BY WATER DECOMPOSITION USING A COMBINED ELECTROLYTIC THERMOCHEMICAL CYCLE**

G. H. Farberman and L. E. Brecher In Miami Univ. First World Hydrogen Energy Conf. Proc., Vol. 1 Mar 1976 22 p refs (For primary document see N77-21552 12-44)

(Contract NAS3-18934)  
Avail: NTIS HC A99/MF A01

A nuclear water decomposition plant was designed which produces electrolytically pure hydrogen at the rate of about 380 million SCF per day, and acquires electric power and thermal energy from a VHTR system of about 3345 MWt. The system is based on the use of sulfur compounds in a hybrid electrolytic-thermochemical cycle; the sulfur cycle water decomposition system. Electric power and heat are used for the electrolytic production of hydrogen and a thermochemical step which closes the cycle and produces oxygen. The combined process operates at an overall thermal efficiency in excess of 45 percent, including the power requirements for plant auxiliaries. The overall economics of hydrogen production by this method were compared to conventional water electrolysis and coal gasification. Costs, prepared on a consistent set of economic ground rules, are presented. It was concluded that nuclear water decomposition plants of the type described show great promise of economic superiority in the time period for which they can practically be developed and put into operation, i.e., the 1990's.

Author

**N77-21602\*** Dow Chemical Co., Walnut Creek, Calif.  
**THE DEVELOPMENT OF A POTASSIUM-SULFIDE GLASS FIBRE CELL AND STUDIES ON IMPURITIES IN ALKALI METAL-SULFUR CELLS**

F Y Tsang Jan 1977 35 p refs

(Contract NAS3-18525)

(NASA-CR-135144) Avail: NTIS HC A03/MF A01 CSCL 10A

Potassium sulfur rechargeable cells, having as the electrolyte the thin walls of hollow glass fibers made from permeable glass, were developed. The cells had short lives, probably due to the construction materials and impurities in the potassium. The effect of the impurities in the analogous Na-S system was studied. Calcium, potassium, and NaOH/oxide impurities caused increased resistance or corrosion of the glass fibers. For long lived cell operation, the Na must contain less than 1 ppm Ca and less than a few ppm of hydroxide/oxide. Up to 150 ppm K can be tolerated. After purification of the Na anolyte, cell lifetimes in excess of 1000 deep charge-discharge cycles or over 8 months on continuous cycling at 10-30 percent depth of discharge were obtained.

Author

**N77-24602\*** Rasor Associates, Inc., Sunnyvale, Calif.  
**ADVANCED THERMIONIC ENERGY CONVERSION: JOINT HIGHLIGHTS Status Report**

May 1976 22 p

(Contracts NAS3-19861; E(11-1)-2263)

(NASA-CR-152955, TID-27200)

Avail: NTIS

HC A02/MF A01 CSCL 10A

A theoretical model was used to study the effects of structured electrodes on converter I-V characteristics and results are given. An auxiliary-ion-source triode operated as a plasmatron was used for studying the enhancement distribution and magnetic effects, and results are reported. Design features of the high current-zero power (ZEPO) converter tests are given.

ERA

**N77-26633\*** Giner, Inc., Waltham, Mass.  
**SCREENING OF REDOX COUPLES AND ELECTRODE MATERIALS Final Report**

J. Giner, L. Swette, and K. Cahill Sep 1976 120 p refs

Sponsored in part by ERDA

(Contract NAS3-19760)

(NASA-CR-134705) Avail: NTIS HC A06/MF A01 CSCL 10C

Electrochemical parameters of selected redox couples that might be potentially promising for application in bulk energy storage systems were investigated. This was carried out in two phases: a broad investigation of the basic characteristics and behavior of various redox couples, followed by a more limited investigation of their electrochemical performance in a redox flow reactor configuration. In the first phase of the program, eight redox couples were evaluated under a variety of conditions in terms of their exchange current densities as measured by the rotating disk electrode procedure. The second phase of the program involved the testing of four couples in a redox reactor under flow conditions with a variety of electrode materials and structures.

Author

**N77-26628\*** Westinghouse Research Labs., Pittsburgh, Pa.  
**ENERGY CONVERSION ALTERNATIVES STUDY (ECAS), PHASE 2, VOLUME 1: SUMMARY AND COMBINED GAS-STREAM TURBINE PLANT WITH AN INTEGRATED LOW-BTU GASIFIER Final Report**

D T Beecher 1 Nov. 1976 497 p refs

(Contracts NAS3-19407; E(49-18)-1751, Grant NSF AG-551)

(NASA-CR-134942-Vol. 1; Rept-76-9E9-ECAS-R2-Vol. 1) Avail: NTIS HC A21/MF A01 CSCL 10B

A parametric analysis of energy conversion concepts using coal or coal derived fuels is presented. Conceptual plant designs were formulated for three advanced power conversion concepts, (1) a combined gas steam turbine cycle whose gas turbines are air cooled, and burn a low Btu gas from coupled pressurized

fluidized bed gasifiers, (2) a combined gas steam turbine cycle whose gas turbine expanders contain ceramic elements and burn a semiclean coal derived liquid from the H coal process, and (3) an advanced steam plant whose steam is pressurized fluidized bed boilers. A detailed analysis of performance, plant layout, capital cost, cost of electricity, natural resource requirements, and emissions of the three advanced concepts is also included.

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**N77-26629\*** Westinghouse Research Labs., Pittsburgh, Pa. **ENERGY CONVERSION ALTERNATIVES STUDY (ECAS), PHASE 2. VOLUME 2: SUMMARY AND COMBINED GAS-STEAM TURBINE PLANT USING COAL DERIVED LIQUID FUEL** Final Report

D T Beecher 15 Oct 1976 334 p refs  
(Contracts NAS3-19407, E(49-18)-1751; Grant NSF AG-551)  
(NASA-CR-134942-Vol-2, Rept-76-9E9-ECAS-R2-Vol-2) Avail:  
NTIS HC A15/MF A01 CSCL 10B

For abstract, see N77-26628

**N77-26630\*** Westinghouse Research Labs., Pittsburgh, Pa. **ENERGY CONVERSION ALTERNATIVES STUDY (ECAS), PHASE 2. VOLUME 3: SUMMARY AND ADVANCED STEAM PLANT WITH PRESSURIZED FLUIDIZED BED BOILERS** Final Report

D T Beecher 1 Nov 1976 398 p refs  
(Contracts NAS3-19407, E(49-18)-1751; Grant NSF AG-551)  
(NASA-CR-134942-Vol-3, Rept-76-9E9-ECAS-R2-Vol-3) Avail:  
NTIS HC A17/MF A01 CSCL 10B

For abstract, see N77-26628

**N77-26631\*** General Electric Co., Schenectady, N.Y. **ENERGY CONVERSION ALTERNATIVES STUDY (ECAS), PHASE 2. VOLUME 1: EXECUTIVE SUMMARY** Final Report

J C Corman and G R Fox Dec 1976 54 p refs  
(Contracts NAS3-19406, E(49-18)-1751; Grant NSF AG-551)  
(NASA-CR-134949-Vol-1, SRD-76-064-1-Vol-1) Avail: NTIS  
HC A04/MF A01 CSCL 10B

A data base for the comparison of advanced energy conversion systems for electric utility baseload applications using coal or coal-derived fuels was developed. Conceptual designs were developed for seven systems to permit estimates of power plant efficiency, capital cost, environmental intrusion characteristics, natural resource requirements, and cost of electricity at an assumed capacity factor of 65%. The systems studied were advanced steam with atmospheric fluidized bed (AFB) and pressurized fluidized bed (PFB) heat input subsystems, a closed helium gas turbine (organic bottoming) with an AFB, a potassium topping cycle with a PFB, a combined cycle gas turbine--water cooled--burning a coal-derived liquid fuel, a combined cycle gas turbine--air cooled--integrated with Lbtu gasification, and an open cycle MHD system. An emissions limit target was specified for the power plant conceptual designs. A steam power plant (3,500 psig/1000 F/1000 F) with a coal-burning radiant furnace and a wet lime stack gas scrubber (stack reheat to 250 F), analyzed in a study using the same groundrules as ECAS, were used as references for comparison. All of the systems exhibited an estimated efficiency better than the 32% reference case. Five of the systems showed a lower cost of electricity than the 39.8 mills/kWh reference case. Development plans and cost estimates were prepared for the energy conversion portion of the respective systems. An implementation assessment was performed to estimate the potential applicability of the advanced energy conversion systems in electric utility generation systems.

Author

**N77-26632\*** General Electric Co., Schenectady, N.Y. **ENERGY CONSERVATION ALTERNATIVES STUDY (ECAS), PHASE 2: VOLUME 2: ADVANCED ENERGY CONVERSION SYSTEMS - CONCEPTUAL DESIGNS. PART 1: ANALYTICAL APPROACH** Final Report

J. C. Corman, A. S. Robertson, R. D. Stewart, T. A. V. Cassel, and G. G. Johnson Dec 1976 97 p refs  
(Contracts NAS3-19406, E(49-18)-1751; Grant NSF AG-551)  
(NASA-CR-134949-Vol-2-Pt-1, SRD-76-064-2-Vol-2-Pt-1)  
Avail: NTIS HC A05/MF A01 CSCL 10B  
For abstract, see N77-26631

**N77-26633\*** General Electric Co., Schenectady, N.Y. **ENERGY CONVERSION ALTERNATIVES STUDY (ECAS), PHASE 2. VOLUME 2: ADVANCED ENERGY CONVERSION SYSTEMS - CONCEPTUAL DESIGNS. PART 2: CLOSED TURBINE CYCLES** Final Report

D. H. Brown, B. D. Pomeroy, and R. P. Shah Dec 1976 274 p refs  
(Contracts NAS3-19406, E(49-18)-1751; Grant NSF AG-551)  
(NASA-CR-134949-Vol-2-Pt-2, SRD-76-064-2-Vol-2-Pt-2)  
Avail: NTIS HC A12/MF A01 CSCL 10B

For abstract, see N77-26631

**N77-26634\*** General Electric Co., Schenectady, N.Y. **ENERGY CONVERSION ALTERNATIVES STUDY (ECAS), PHASE 2. VOLUME 2: ADVANCED ENERGY CONVERSION SYSTEMS - CONCEPTUAL DESIGNS. PART 3: OPEN CYCLE GAS TURBINES AND OPEN CYCLE MHD** Final Report

L P Harris and R P Shah Dec 1976 277 p refs  
(Contract NAS3-19406, E(49-18)-1751; Grant NSF AG-551)  
(NASA-CR-134949-Vol-2-Pt-3, SRD-76-064-2-Vol-2-Pt-3)  
Avail: NTIS HC A13/MF A01 CSCL 10B

For abstract, see N77-26631

**N77-26635\*** General Electric Co., Schenectady, N.Y. **ENERGY CONVERSION ALTERNATIVES STUDY (ECAS), PHASE 2. VOLUME 3: ADVANCED ENERGY CONVERSION SYSTEMS: CONCEPTUAL DESIGNS. PART 4: SUMMARY OF RESULTS** Final Report

D. H. Brown, J. C. Corman, G. G. Johnson, W. J. MacFarland, B. D. Pomeroy, and D. A. Woodford Dec 1976 92 p refs  
(Contracts NAS3-19406, E(49-18)-1751; Grant NSF AG-551)  
(NASA-CR-134949-Vol-2-Pt-4, SRD-76-064-2-Vol-2-Pt-4)  
Avail: NTIS HC A05/MF A01 CSCL 10B

For abstract, see N77-26631

**N77-26636\*** General Electric Co., Schenectady, N.Y. **ENERGY CONVERSION ALTERNATIVES STUDY (ECAS), PHASE 2. VOLUME 3: RESEARCH AND DEVELOPMENT PLANS AND IMPLEMENTATION ASSESSMENT** Final Report

R. R. Bass, D. H. Brown, J. C. Corman, L. P. Harris, B. D. Pomeroy, and R. P. Shah Dec 1976 347 p refs  
(Contracts NAS3-19406, E(49-18)-1751; Grant NSF AG-551)  
(NASA-CR-134949-Vol-3, SRD-76-064-3) Avail: NTIS  
HC A15/MF A01 CSCL 10B

For abstract, see N77-26631

**N77-26637\*** United Technologies Corp., South Windsor, Conn. **ENERGY CONVERSION ALTERNATIVES STUDY (ECAS), PHASE 2. INTEGRATED COAL GASIFIER/MOLTEN CARBONATE FUEL CELL POWERPLANT CONCEPTUAL DESIGN AND IMPLEMENTATION ASSESSMENT** Final Report

J. M. King 19 Oct 1976 171 p refs Prepared in cooperation with Burns and Roe, Inc. and the Inst. of Gas Technol  
(Contract NAS3-19586)

(NASA-CR-134955, FCR-0237) Avail: NTIS  
HC A08/MF A01 CSCL 10A

For abstract, see N77-26631

**N77-27486\*** Westinghouse Electric Corp., Lester, Pa. Generation Systems Div.

**ANALYTICAL INVESTIGATION OF THERMAL BARRIER COATINGS ON ADVANCED POWER GENERATION GAS TURBINES**

D. J. Amos. Mar. 1977. 110 p refs.  
(Contract NAS3-19407)

(NASA-CR-135146, EM-1636) Avail: NTIS HC A05/MF A01 CSCL 10B

An analytical investigation of present and advanced gas turbine power generation cycles incorporating thermal barrier turbine component coatings was performed. Approximately 50 parametric points considering simple, recuperated, and combined cycles (including gasification) with gas turbine inlet temperatures from current levels through 1644K (2500 F) were evaluated. The results indicated that thermal barriers would be an attractive means to improve performance and reduce cost of electricity for these cycles. A recommended thermal barrier development program has been defined. Author

**N77-27496\*** United Technologies Corp., South Windsor, Conn. Power Systems Div.

**THERMAL BARRIER COATING ON HIGH TEMPERATURE INDUSTRIAL GAS TURBINE ENGINES. Final Report**

Nils Carlson and Barry L. Stoner (Pratt and Whitney Aircraft, East Hartford, Conn.) Feb. 1977. 60 p.  
(Contracts NAS3-20067, e(49-28)-1022)

(NASA-CR-135147, ERDA/NASA-0067/77/1; PSD-R-109) Avail: NTIS HC A04/MF A01 CSCL 10B

The thermal barrier coating used was a yttria stabilized zirconia material with a NiCrAlY undercoat, and the base engine used to establish improvements was the P&WA FT50A-4 industrial gas turbine engine. The design benefits of thermal barrier coatings include simplified cooling schemes and the use of conventional alloys in the engine hot section. Cooling flow reductions and improved heating rates achieved with thermal barrier coating result in improved performance. Economic benefits include reduced power production costs and reduced fuel consumption. Over the 30,000 hour life of the thermal barrier coated parts, fuel savings equivalent to \$5 million are projected and specific power (megawatts/mass of engine airflow) improvements on the order of 13% are estimated. Author

**N77-28588\*** Rasor Associates, Inc., Sunnyvale, Calif.

**THE PLASMATRON: ADVANCED MODE THERMIONIC ENERGY CONVERSION**

L. K. Hansen, G. L. Hatch, and N. S. Rasor. Nov. 1976. 65 p refs.

(Contract NAS3-19861)

(NASA-CR-135139, NSR-5-1) Avail: NTIS HC A04/MF A01 CSCL 10A

A theory of the plasmatron was developed. Also, a wide range of measurements were obtained with two versatile, research devices. To gain insight into plasmatron performance, the experimental results are compared with calculations based on the theoretical model of plasmatron operation. Results are presented which show that the plasma arc drop of the conventional arc (ignited) mode converter can be suppressed by use of an auxiliary ion source. The improved performance, however, is presently limited to low current densities because of voltage losses due to plasma resistance. This resistance loss could be suppressed by an increase in the plasma electron temperature or a decrease in spacing. Plasmatron performance characteristics for both argon and cesium are reported. The argon plasmatron has superior performance. Results are also presented for magnetic cutoff effects and for current distributing effects. These are shown to be important factors for the design of practical devices. Author

**N77-29604\*** Spectrolab, Inc., Sylmar, Calif.  
**DEVELOPMENT OF STANDARDIZED SPECIFICATIONS FOR SILICON SOLAR CELLS. Final Contractor Report**

John A. Scott-Monck. Aug. 1977. 83 p refs.  
(Contract NAS3-19440)

(NASA-CR-135233, Rept-380-6240) Avail: NTIS HC A05/MF A01 CSCL 10A

A space silicon solar cell assembly (cell and coverglass) specification aimed at standardizing the diverse requirements of current cell or assembly specifications was developed. This specification was designed to minimize both the procurement and manufacturing costs for space qualified silicon solar cell assemblies. In addition, an impact analysis estimating the technological and economic effects of employing a standardized space silicon solar cell assembly was performed. Author

**N77-30610\*** Energy Research Corp., Danbury, Conn.  
**FABRICATION AND TESTING OF LARGE SIZE NICKEL-ZINC CELLS**

Martin Klein. Apr. 1977. 62 p ref.  
(Contract NAS3-19415)

(NASA-CR-135200) Avail: NTIS HC A04/MF A01 CSCL 10C

The design and construction of nickel zinc cells, containing sintered nickel electrodes and asbestos coated inorganic separator materials, were outlined. Negative electrodes were prepared by a dry pressing process while various inter-separators were utilized on the positive electrodes, consisting of non-woven nylon, non-woven polypropylene, and asbestos. Author

**N77-31613\*** Raytheon Co., Wayland, Mass. Microwave and Power Tube Div.

**ELECTRONIC AND MECHANICAL IMPROVEMENT OF THE RECEIVING TERMINAL OF A FREE-SPACE MICROWAVE POWER TRANSMISSION SYSTEM**

William C. Brown. 1 Aug. 1977. 158 p refs.  
(Contract NAS3-19722)

(NASA-CR-135194, PT-4964) Avail: NTIS HC A08/MF A01 CSCL 10A

Significant advancements were made in a number of areas, improved efficiency of basic receiving element at low power density levels, improved resolution and confidence in efficiency measurements, mathematical modelling and computer simulation of the receiving element and the design, construction, and testing of an environmentally protected two-plane construction suitable for low cost, highly automated construction of large receiving arrays. Author

**N77-32590\*** Spectrolab, Inc., Sylmar, Calif.  
**AUTOMATED FABRICATION OF BACK SURFACE FIELD SILICON SOLAR CELLS WITH SCREEN PRINTED WRAP-AROUND CONTACTS. Final Report**

J. W. Thornhill. Aug. 1977. 49 p.  
(Contract NAS3-20029)

(NASA-CR-135202, Rept-380-5313) Avail: NTIS HC A03/MF A01 CSCL 10A

The development of a process for fabricating 2 x 4 cm back surface field silicon solar cells having screen printed wraparound contacts is described. This process was specifically designed to be amenable for incorporation into the automated nonvacuum production line. Techniques were developed to permit the use of screen printing for producing improved back surface field structures, wraparound electric layers, and wraparound contacts. The optimized process sequence was then used to produce 1852 finished cells. Tests indicated an average conversion efficiency of 11% at AMO and 28 C, with an average degradation of maximum power output of 1.5% after boiling water immersion or thermal shock cycling. Contact adherence was satisfactory after these tests, as well as long term storage at high temperature and high humidity. Author

**N77-32692\*** Thermo Electron Corp., Waltham, Mass.  
**HIGH EFFICIENCY THERMIONIC CONVERTER STUDIES. Technical Report, 1 Jul. 1978 - 30 Apr. 1977**

F. N. Huffman, A. H. Sommer, C. L. Balastra, T. R. Briere, D. P. Lieb, P. E. Oettinger, and D. B. Goodale. Jul. 1977. 98 p refs.

(Contract NAS3-20302)  
(NASA-CR-135263; TE-4233-152-77) Avail: NTIS  
HC A05/MF A01 CSCL 10A

Research in thermionic energy conversion technology is reported. The objectives were to produce converters suitable for use in out of core space reactors, radioisotope generators, and solar satellites. The development of emitter electrodes that operate at low cesium pressure, stable low work function collector electrodes, and more efficient means of space charge neutralization were investigated to improve thermionic converter performance. Potential improvements in collector properties were noted with evaporated thin film, barium oxide coatings. Experiments with cesium carbonate suggest this substance may provide optimum combinations of cesium and oxygen for thermionic conversion.

Author

**N77-33608\*** Exxon Research and Engineering Co. Linden  
N. J. Government Research Labs.

**REDOX BULK ENERGY STORAGE SYSTEM STUDY.**

**VOLUME 1 Final Report, 18 Feb. 1976 - 30 Jan. 1977**

G. Ciprios, W. Erskine, Jr. and P. G. Grimes 10 Feb. 1977  
200 p refs 2 Vol.

(Contract NAS3-19776)

(NASA-CR-135206-Vol-1; EXXON/GRU 1BH-77-Vol-1) Avail  
NTIS HC A09/MF A01 CSCL 10B

Opportunities were found for electrochemical energy storage devices in the U.S. electric utility industry. Application requirements for these devices were defined, including techno-economic factors. A new device, the Redox storage battery was analyzed. The Redox battery features a decoupling of energy storage and power conversion functions. General computer methods were developed to simulate Redox system operations. These studies showed that the Redox system is potentially attractive if certain performance goals can be achieved. Pathways for reducing the cost of the Redox system were identified.

Author

**N77-33609\*** Exxon Research and Engineering Co. Linden  
N. J. Government Research Labs.

**REDOX BULK ENERGY STORAGE SYSTEM STUDY.**

**VOLUME 2 Final Report, 18 Feb. 1976 - 30 Jan. 1977**

G. Ciprios, W. Erskine, Jr. and P. G. Grimes 10 Feb. 1977  
549 p refs

(Contract NAS3-19776)

(NASA-CR-135206-Vol-2; EXXON/GRU 2BH-77-Vol-2) Avail  
NTIS HC A23/MF A01 CSCL 10B

For abstract, see N77-33608.

**A77-12791\*** Nuclear driven water decomposition plant for hydrogen production. G. H. Parker, L. E. Brecher, and G. H. Farberman (Westinghouse Electric Corp., Advanced Energy Systems Div., Pittsburgh, Pa.). In: Intersociety Energy Conversion Engineering Conference, 11th, State Line, Nev., September 12-17, 1976, Proceedings, Volume 2. (A77-12662 02-44) New York, American Institute of Chemical Engineers, 1976, p. 1095-1101. Contract No. NAS3-18934.

The conceptual design of a hydrogen production plant using a very-high-temperature nuclear reactor (VHTR) to energize a hybrid electrolytic-thermochemical system for water decomposition has been prepared. A graphite-moderated helium-cooled VHTR is used to produce 1850 F gas for electric power generation and 1600 F process heat for the water-decomposition process which uses sulfur compounds and promises performance superior to normal water electrolysis or other published thermochemical processes. The combined cycle operates at an overall thermal efficiency in excess of 45%, and the overall economics of hydrogen production by this plant have been evaluated predicated on a consistent set of economic ground rules. The conceptual design and evaluation efforts have indicated that development of this type of nuclear-driven water-decomposition plant will permit large-scale economic generation of hydrogen in the 1990s.

(Author)

**A77-12862\*** Advanced thermionic converter development. F. N. Huffman, D. Lieb, T. R. Briere, A. H. Sommer and F. Rufe (Thermo Electron Corp., Waltham, Mass.). In: Intersociety Energy Conversion Engineering Conference, 11th, State Line, Nev., September 12-17, 1976, Proceedings, Volume 2. (A77-12662 02-44) New York, American Institute of Chemical Engineers, 1976, p. 1645-1651. 5 refs. Contracts No. E(11-1)-3056; No. NAS3-19866.

Recent progress at Thermo Electron in developing advanced thermionic converters is summarized with particular attention paid to the development of electrodes, diodes, and triodes. It is found that one class of materials (ZnO, BaO and SrO) provides interesting cesiated work functions (1.3-1.4 eV) without additional oxygen. The second class of materials studied (rare earth oxides and hexaborides) gives cesiated/oxygenated work functions of less than 1.2 eV. Five techniques of oxygen addition to thermionic converters are discussed. Vapor deposited tungsten oxide collector diodes and the reflux converter are considered.

B.J.

**A77-33363\*** Heat transfer analysis of metal hydrides in metal-hydrogen secondary batteries. M. Onischak, D. Dharja (Energy Research Corp., Danbury, Conn.), and D. Gidaszow (IIT Institute of Gas Technology, Chicago, Ill.). In: World Hydrogen Energy Conference, 1st, Miami Beach, Fla., March 1-3, 1976, Proceedings, Volume 2. (A77-33326 14-44) Coral Gables, Fla., University of Miami; New York, Pergamon Press, 1976, p. 7B-37 to 7B-51. Contract No. NAS3-18557.

The heat transfer between a metal-hydrogen secondary battery and a hydrogen-storing metal hydride was studied. Temperature profiles of the endothermic metal hydrides and the metal-hydrogen battery were obtained during discharging of the batteries assuming an adiabatic system. Two hydride materials were considered in two physical arrangements within the battery system. In one case the hydride is positioned in a thin annular region about the battery stack; in the other the hydride is held in a tube down the center of the stack. The results show that for a typical 20 ampere-hour battery system with lanthanum pentanickel hydride as the hydrogen reservoir the system could perform successfully.

(Author)

**A77-37960\*** Future trends in electrical energy generation economics in the United States. R. W. Schmitt, G. R. Fox, R. P. Shah, P. J. Stewart, and D. A. Vermilyea (General Electric Co., Schenectady, N.Y.). Ministry for Electrical Engineering Industries of USSR and Academy of Sciences of USSR, World Electrotechnical Congress, Moscow, USSR, June 21-25, 1977, Paper. 49 p. 7 refs. Contract No. NAS3-19406.

Developments related to the economics of coal-fired systems in the U.S. are mainly considered. The historical background of the U.S. electric generation industry is examined and the U.S. electrical generation characteristics in the year 1975 are considered. It is pointed out that coal-fired power plants are presently the largest source of electrical energy generation in the U.S. Questions concerning the availability and quality of coal are investigated. Currently there are plans for converting some 50 large oil and gas-fired generating plants to coal, and it is expected that coal will be the fuel used in almost all fossil-fired base load additions to generating capacity. Aspects of advanced energy conversion from coal are discussed, taking into account the performance and economic potential of the energy conversion systems.

G.R.

**A77-38211\*** Conceptual design of a parabolic dish solar collector using simulation techniques. B. P. Gupta and R. L. Buchholz (Honeywell Energy Resources Center, Minneapolis, Minn.). In: Modeling and simulation. Volume 7: Proceedings of the Seventh Annual Pittsburgh Conference, Pittsburgh, Pa., April 26, 27, 1976, Part 1. (A77-38176 17-66) Pittsburgh, Pa., Instrument Society of America, 1976, p. 646-650. Contract No. NAS3-19740.

The development of solar concentrators in recent years have produced a wide variety of collectors for the utilization of solar energy. This paper presents the simulation techniques used to predict

the optical and thermal performance of a paraboloid of revolution type solar collector. Conceptual design of a dish concentrator with a fixed receiver size is obtained by parametrically examining the significant variables. (Author)

**A77-48887 \*** Thermionic converter studies at Thermo Electron. F. N. Huffman, D. Lieb, and F. Ruloh (Thermo Electron Corp., Waltham, Mass.). In: Intersociety Energy Conversion Engineering Conference, 12th, Washington, D.C., August 28-September 2, 1977, Proceedings. Volume 2. (A77-48701 23-44) La Grange Park, Ill., American Nuclear Society, Inc., 1977, p. 1548-1554. 19 refs. Grant No. EX-76-C-02-3056; Contract No. NAS3-20302.

The Thermionic Energy Converter (TEC) development program includes theoretical and experimental surface studies, diode evaluation, enhanced mode converter investigations and system studies, as well as materials fabrication and testing. The primary effort has been concentrated on increasing converter performance via improved electrodes. Diodes with oxide collectors (i.e., tungsten oxide, titanium oxide, zinc oxide and barium oxide) have provided the best performance. Emitters requiring reduced cesium pressure (such as oxygenated tungsten, lanthanum hexaboride, platinum and graphite) are being tested. Converter configurations using particle spacing are under investigation. Experiments with auxiliary electrode thermionic converters are in progress. Both silicon carbide and alloy hot shells (i.e., barriers to isolate the converter from the combustion environment) have been fabricated and tested. (Author)

**A77-48888 \*** Thermionic converter performance with oxide collectors. D. Lieb, D. Goodale, T. Briere, and C. Balestra (Thermo Electron Corp., Waltham, Mass.). In: Intersociety Energy Conversion Engineering Conference, 12th, Washington, D.C., August 28-September 2, 1977, Proceedings. Volume 2. (A77-48701 23-44) La Grange Park, Ill., American Nuclear Society, Inc., 1977, p. 1555-1562. 6 refs. Grant No. EY-76-C-02-3056; Contract No. NAS3-20302.

Thermionic converters using a variety of metal oxide collector surfaces have been fabricated and tested. Both work function and power output data are presented and evaluated. Oxides of barium, strontium, zinc, tungsten and titanium have been incorporated into a variable spacing converter. Tungsten oxide was found to give the highest converter performance and to furnish oxygen for the emitter at the same time. Oxygenated emitters operate at reduced cesium pressure with an increase in electrode spacing. Electron spectroscopy for chemical analysis (ESCA) performed on several tungsten oxide collectors showed cesium penetration of the oxide layer, possibly forming a cesium tungstate bronze. Titanium oxide showed high performance but did not furnish oxygen for the emitter, strontium oxide, in the form of a sprayed layer, appeared to dissociate in the presence of cesium. Sprayed coatings of barium and zinc oxides produced collector work functions of about 1.3 eV, but had excessive series resistance. Lanthanum hexaboride, in combination with oxygen introduced through a silver tube, and cesium produced a low work function collector and better than average performance. (Author)

**A77-48898 \*** Experimental data and theoretical analysis of an operating 100 kW wind turbine. B. S. Linscott, J. Glasgow (NASA, Lewis Research Center, Cleveland, Ohio), W. D. Anderson, and R. E. Donham (Lockheed California Co., Burbank, Calif.). In: Intersociety Energy Conversion Engineering Conference, 12th, Washington, D.C., August 28-September 2, 1977, Proceedings. Volume 2. (A77-48701 23-44) La Grange Park, Ill., American Nuclear Society, Inc., 1977, p. 1633-1650. 8 refs. Contract No. NAS3-20036.

Part of the cooperative effort between NASA and ERDA has been the design and the erection of an experimental wind turbine by the NASA-Lewis Research Center. This 100 kW turbine, designated the Mod-O, is located at the NASA Plum Brook site near Sandusky, Ohio. Experimental test data have been correlated with analyses of turbine loads and complete system behavior of the 100 kW Mod-O

wind turbine generator over a broad range of steady state conditions, as well as during transient conditions. The deficit in the ambient wind field due to the upwind tower turbine support structure was found to be very significant in exciting higher harmonic loads associated with the flapping response of the blade in bending. (Author)

**A77-49034 \*** Technical feasibility of a modular dish solar electric system. B. P. Gupta (Honeywell Energy Resources Center, Minneapolis, Minn.). In: Sharing the sun: Solar technology in the seventies; Proceedings of the Joint Conference, Winnipeg, Canada, August 15-20, 1976. Volume 5. (A77-48910 23-44) Cape Canaveral, Fla., International Solar Energy Society, 1976, p. 291-309. Contract No. NAS3-19740.

The paper presents the technical feasibility of generating electricity by using a gas turbine in conjunction with a paraboloid of revolution (dish) solar concentrator. A conceptual design of a dish concentrator is obtained by parametrically examining the significant optical parameters. The optical performance analysis was conducted using a Monte Carlo ray trace simulation program. The performance of four candidate thermodynamic cycles utilizing two working fluids was analyzed, the cycles were the regenerative and nonregenerative Brayton cycles of both open and closed type. Air and helium were the working fluids for the open and closed type respectively. Heat transfer from the solar radiation to the gas flowing in metal tubes at the receiver was also analyzed. A paraboloid of revolution dish with a cavity receiver using an open air regenerative Brayton cycle turbine emerged as a technically feasible concept in the power range from 30 to 100 KWth per module. (Author)

## 45 ENVIRONMENT POLLUTION

Includes air, noise, thermal and water pollution; environment monitoring; and contamination control.

**N77-13583\*** National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio.

### **NASA GLOBAL ATMOSPHERIC SAMPLING PROGRAM (GASP) DATA REPORT FOR TAPE VLO004**

J. D. Holdeman, F. M. Humenik, and E. A. Lezberg Nov. 1976 47 p refs  
(NASA-TM-X-73574; E-9023) Avail: NTIS HC A03/MF A01 CSCL 04A

The NASA Global Atmospheric Sampling Program (GASP) is obtaining measurements of atmospheric trace constituents in the upper troposphere and lower stratosphere using fully automated air sampling systems on board several commercial B-747 aircraft in routine airline service. Atmospheric ozone, water vapor, and related flight and meteorological data were obtained during 139 flights of a United Airlines B-747 and a Pan American World Airways B-747 from December 1975 through March 1976. In addition, sample bottles were exposed during three flights and analyzed for trichlorofluoromethane, and filter samples were exposed during five flights and analyzed for sulfates, nitrates, and chlorides. Flight routes and dates, instrumentation, data processing procedures, data tape specifications, and selected analyses are discussed. Author

**N77-18603\*** National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio.

### **NASA GLOBAL ATMOSPHERIC SAMPLING PROGRAM (GASP) DATA REPORT FOR TAPE VLO005**

J. D. Holdeman and F. M. Humenik Feb. 1977 45 p refs  
(NASA-TM-X-73608; E-9086) Avail: NTIS HC A03/MF A01 CSCL 13B

Atmospheric ozone, water vapor, and related flight and meteorological data were obtained during 214 flights of a United Airlines B-747 and two Pan American World Airways B-747's from March through June 1976. In addition, trichlorofluoromethane data obtained from laboratory analysis of two whole air samples collected in flight are reported. These data are available on GASP tape VLO005 from the National Climatic Center, Asheville, North Carolina. In addition to the GASP data, tropopause pressure fields obtained from NMC archives for the dates of the GASP flights are included on the data tape. Flight routes and dates, instrumentation, data processing procedures, and data tape specifications are described in this report. Selected analyses including ozone and sample bottle data are also presented. Author

**N77-21735\*** National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio.

### **COMPARISON OF OZONE MEASUREMENT TECHNIQUES USING AIRCRAFT, BALLOON, AND GROUND-BASED MEASUREMENTS**

Daniel Briehl and Gregory M. Reck Washington Apr. 1977 18 p refs  
(NASA-TM-X-3520; E-8951) Avail: NTIS HC A02/MF A01 CSCL 04A

In order to verify the ultraviolet absorption technique used in the Global Atmospheric Sampling Program, two flight experiments were conducted employing several techniques, both in situ and remote, for measuring atmospheric ozone. The first experiment used the NASA CV-990 equipped with an ultraviolet absorption ozone monitor and an ultraviolet spectrophotometer, a balloon ozonesonde, and a Dobson station for determining and comparing the ozone concentration data. A second experiment compared ozone data from an automated sampling system aboard a B-747 with data from a manned system installed on the NASA CV-990 during a cross-country flight with both aircraft following the same flight path separated by 32 kilometers. Author

**N77-22689\*** National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio.

### **ION CHROMATOGRAPHIC DETERMINATION OF ANIONS COLLECTED ON FILTERS AT ALTITUDES BETWEEN 9.6 AND 13.7 KILOMETERS**

Dumas A. Otterson 1977 16 p refs Presented at Symp. on Ion Chromatog. Analysis of Environ. Pollutants, Research Triangle Park, N. C., 28 Apr. 1977; sponsored by EPA  
(NASA-TM-X-73642; E-9143) Avail: NTIS HC A02/MF A01 CSCL 13B

The investigation of atmospheric pollution to determine the anion-containing particulates in the atmosphere at altitudes between 9.6 and 13.7 km is discussed. Air samples collected on cellulose fiber discs impregnated with dibutoxyethylphthalate require very sensitive methods of analysis. It is concluded that ion chromatography is suited for the determination of anions collected on the filters. Methods to control contamination and interfering side reactions are described. J.M.S.

**N77-26701\*** National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio.

### **IN SITU MEASUREMENTS OF ARCTIC ATMOSPHERIC TRACE CONSTITUENTS FROM AN AIRCRAFT**

Gregory M. Reck, Daniel Briehl, and Ted W. Nyland Washington Jun. 1977 64 p refs  
(NASA-TN-D-8491; E-9040) Avail: NTIS HC A04/MF A01 CSCL 13B

In situ measurements of the ambient concentrations of several atmospheric trace constituents were obtained using instruments installed on board the NASA Convair 990 aircraft at altitudes up to 12.5 kilometers over Alaska and the Arctic Ocean. Concentration data on ozone, carbon monoxide, water vapor, and particles larger than 0.5 micrometer in diameter were acquired. Author

**N77-27568\*** National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio.

### **INTERHEMISPHERIC SURVEY OF MINOR UPPER ATMOSPHERIC CONSTITUENTS DURING OCTOBER - NOVEMBER 1976**

Daniel J. Gauntner, comp. and Louis C. Haughney, comp. (NASA, Ames Res. Center) Mar. 1977 201 p refs  
(NASA-TM-X-73630; E-9130) Avail: NTIS HC A10/MF A01 CSCL 13B

The CV-990 aircraft coordinated several flights with a NASA U-2 aircraft, NOAA ground station measurements in Alaska, Hawaii, and American Samoa, and with Australian and New Zealand ground stations, aircraft, and a balloon experiment in the Southern hemisphere. Data were obtained for species including ozone, total ozone, the oxides of nitrogen, the chlorofluoromethanes, water vapor, nitric acid, carbon monoxide, carbon dioxide, hydrogen chloride, Aitken nuclei, ammonia, aerosols, temperatures, and winds. Individual experiment results and selected analyses are presented. The experimental data include total column densities, latitude variations, interhemisphere differences, and vertical profiles. Author

**N77-28622\*** National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio.

### **NASA GLOBAL ATMOSPHERIC SAMPLING PROGRAM (GASP) DATA REPORT FOR TAPE VLO006**

Daniel J. Gauntner, J. D. Holdman, and Francis M. Humenik Jul. 1977 43 p refs  
(NASA-TM-73727; E-9284) Avail: NTIS HC A03/MF A01 CSCL 13B

The NASA Global Atmospheric Sampling Program (GASP) is obtaining measurements of atmospheric trace constituents in the upper troposphere and lower stratosphere using fully automated air sampling systems on board several commercial B-747 aircraft in routine airline service. Atmospheric ozone, and related flight and meteorological data were obtained during 245 flights of a Qantas Airways of Australia B-747 and two Pan



American World Airways B-747s from July 1976 through September 1976. In addition, whole air samples, obtained during three flights, were analyzed for trichlorofluoromethane, and filter samples, obtained during four flights, were analyzed for sulfates, nitrates, fluorides, and chlorides. Flight routes and dates, instrumentation, data processing procedures, data tape specifications, and selected analyses are discussed. Author

**A77-12267 \*** Elemental composition of airborne particulates and source identification - An extensive one year survey. R. B. King, J. S. Fordyce, A. C. Antoine, H. F. Leibecki, H. E. Neustadter, and S. M. Sidik (NASA, Lewis Research Center, Environmental Monitoring Systems Office, Cleveland, Ohio). *Air Pollution Control Association, Journal*, vol. 26, Nov. 1976, p. 1073-1078, 25 refs.

Concentrations of 60 chemical elements in the airborne particulate matter were measured at 16 sites in Cleveland, OH over a 1 year period during 1971 and 1972 (45 to 50 sampling days). Analytical methods used included instrumental neutron activation, emission spectroscopy, and combustion techniques. Uncertainties in the concentrations associated with the sampling procedures, the analytical methods, the use of several analytical facilities, and samples with concentrations below the detection limits are evaluated in detail. The data are discussed in relation to other studies and source origins. The trace constituent concentrations as a function of wind direction are used to suggest a practical method for air pollution source identification. (Author)

**A77-47259 \*** Compounds in airborne particulates - Salts and hydrocarbons. R. B. King, A. C. Antoine, J. S. Fordyce, H. E. Neustadter, and H. F. Leibecki (NASA, Lewis Research Center, Cleveland, Ohio). *Air Pollution Control Association, Journal*, vol. 27, Sept. 1977, p. 869-871, 32 refs.

Concentrations of 10 polycyclic aromatic hydrocarbons (PAH), the aliphatics as a group, sulfate, nitrate, fluoride, acidity, and carbon in the airborne particulate matter were measured at 16 sites in Cleveland, OH over a 1-year period during 1971 and 1972. Analytical methods used included gas chromatography, colorimetry, and combustion techniques. Uncertainties in the concentrations associated with the sampling procedures, and the analytical methods are evaluated. The data are discussed relative to other studies and source origins. High concentrations downwind of coke ovens for 3,4 benzopyrene are discussed. Hydrocarbon correlation studies indicated no significant relations among compounds studied. (Author)

**N77-33684\*/** Panametrics, Inc., Waltham, Mass.  
**TOTAL OZONE DERIVED FROM UV SPECTROPHOTOMETER MEASUREMENTS ON THE NASA CV-990 AIRCRAFT FOR THE FALL 1976 LATITUDE SURVEY FLIGHTS Final Report**

Frederick A. Hanser Oct. 1977 93 p refs  
 (Contract NAS3-20472)

(NASA-CR-135276; PANA-UVS-9) Avail: NTIS  
 HC A05/MF A01 CSCL 08K

An ultraviolet interference filter spectrophotometer was modified to use a photodiode and was flown on latitude survey flights in the fall of 1976. Comparison with Dobson station total ozone values shows agreement between UVS and Dobson total ozone of + or - 2 percent. The procedure used to convert UVS measured ozone above the aircraft altitude to total ozone above ground level introduces an additional 2 percent deviation for very high altitude UVS ozone data. Under stable aircraft operating conditions, the UVS derived ozone values have a variability, or reproducibility, of better than + or - 1 percent. The UVS data from the latitude survey flights yield a detailed latitude profile of total ozone over the Pacific Ocean during November 1976. Significant latitudinal structure in total ozone is found at the middle latitudes (30 deg to 40 deg N and S).

Author

## 46 GEOPHYSICS

Includes aeronomy; upper and lower atmosphere studies; ionospheric and magnetospheric physics; and geomagnetism.

For space radiation see 93 Space Radiation.

**N77-11612\*** National Aeronautics and Space Administration, Lewis Research Center, Cleveland, Ohio.

### GLOBAL MEASUREMENTS OF GASEOUS AND AEROSOL TRACE SPECIES IN THE UPPER TROPOSPHERE AND LOWER STRATOSPHERE FROM DAILY FLIGHTS OF 747 AIRLINERS

Porter J. Perkins 1976 17 p refs Presented at the Joint Symp. of the Am. Geophys. Union, the AIAA, and the Am. Meteorol. Soc., Miami, Fla., 10-12 Nov. 1976 (NASA-TM-X-73544; E-8945) Avail: NTIS HC A02/MF A01 CSCL 04A

Extensive measurements include ozone, carbon monoxide, water vapor, and aerosol and condensation nuclei number density. Less extensive measurements include chlorofluoromethanes, sulfates and nitrates. Certain meteorological and flight information are also recorded at the time of these measurements. World routes range in latitude from about 60 deg N near North America to about 40 deg S over Australia and 23 deg S over South America. Typical data show significant changes in ozone, carbon monoxide, and water vapor when crossing the tropopause either during changes in altitude or at cruise altitude. These gases as well as light scattering particles and condensation nuclei exhibit considerable variability along a flight route. Author

**N77-30679\*** National Aeronautics and Space Administration, Lewis Research Center, Cleveland, Ohio.

### ATMOSPHERIC OZONE MEASUREMENTS MADE FROM B-747 AIRLINERS: SPRING 1976

P. D. Falconer (NOAA Air Resources Lab., Silver Spring, Md.), J. D. Holdeman (NOAA Air Resources Lab., Silver Spring, Md.), and A. D. Taylor 17 Aug. 1976 17 p refs Presented at the Joint Symp. on Atmospheric Ozone, Dresden, 9-17 Aug. 1976; cosponsored by Intern. Assoc. of Meteorology and Atmospheric Phys., the World Meteorol. Organ., and the Intern. Assoc. of Geomagnetism and Aeronomy (NASA-TM-X-73675) Avail: NTIS HC A02/MF A01 CSCL 04A

Atmospheric ozone in the upper troposphere and lower stratosphere north of the equator has been registered aboard two commercial B-747 airliners. The composite ozone, flight and meteorological data are reported. Attention is drawn particularly to the vertical profiles of atmospheric ozone mixing ratio as a function of both distance from the tropopause and curvature of the streamlines. The GASP observations suggest that ozone levels typical of the lower stratosphere are often embedded in the upper troposphere, principally during occasions when cyclonic wind curvature was noted. Author

**N77-33720\*** National Aeronautics and Space Administration, Lewis Research Center, Cleveland, Ohio.

### DESCRIPTION AND REVIEW OF GLOBAL MEASUREMENTS OF ATMOSPHERIC SPECIES FROM GASP

Daniel J. Gaunter, J. D. Holdeman, Daniel Briehl, and Francis M. Humenik Aug. 1977 25 p refs Presented at Conf. on Air Quality Meteorology and Atmospheric Ozone, Boulder, Colo., 31 Jul. - 6 Aug. 1977; cosponsored by Am. Soc. for Testing and Mater. Comm. D-22, Am. Meteorol. Soc., Air Pollution Control Assoc., EPA, Intern. Ozone Inst., NBS, and NOAA (NASA-TM-73781; E-9338) Avail: NTIS HC A02/MF A01 CSCL 04A

Aerosol composition data were collected with a NASA F-106 aircraft. Present measurements include ozone, carbon monoxide, water vapor, aerosol and condensation nuclei number densities, sulphates, nitrates, and the chlorofluoromethanes. Meteorological and flight parameters are also recorded for use in data analysis.

The present aircraft operations obtain data between 6 and 13.5 km from 65 degree N between Europe and the north Pacific, and from 23 degree S over South America and 42 degree S over New Zealand. Typical constituent data from the aircraft operations during the first one and a half years are presented. Instrumentation is discussed. Author

**N77-21770\*** Control Data Corp., Minneapolis, Minn. Research Div.

### VARIABILITY AND TRANSPORT OF OZONE AT THE TROPOPAUSE FROM THE FIRST YEAR OF GASP DATA

G. D. Nastrom Feb. 1977 32 p refs (Contract NAS2-7807) (NASA-CR-135176; RR-4) Avail: NTIS HC A03/MF A01 CSCL 04A

The relationships of ozone near the tropopause with potential vorticity, temperature, and distance from the tropopause are examined. Data are also used to estimate the vertical and horizontal fluxes of ozone near the tropopause. The present estimates of the total flux of ozone into the troposphere verify the model results. Although the distribution of flux between mean motions and diffusion is different and thus suggests that models with coarse horizontal resolution must continue to parameterize much vertical transport by diffusion coefficients. Monthly estimates of the horizontal transient eddy flux of ozone are generally smaller than seasonal or yearly results based on ozonesonde data. This is perhaps because the present estimates are made over monthly periods to reduce the influence of correlation between the annual variations in ozone and meridional wind. The available data support the hypothesis that transient eddy fluxes of ozone have large longitudinal variations. Author

## 47 METEOROLOGY AND CLIMATOLOGY

Includes weather forecasting and modification.

**N77-19714\*** National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio.

### **CORRELATION OF TOTAL, DIFFUSE, AND DIRECT SOLAR RADIATION**

Edgar H. Buyco (Purdue Univ., Hammond, Ind.) and David Namkoong Washington Mar 1977 25 p refs (NASA-TM-X-3422: E-8867) Avail: NTIS HC A02/MF A01 CSCI 04B

Present requirements for realistic solar energy system evaluations necessitate a comprehensive body of solar-radiation data. The data should include both diffuse and direct solar radiation as well as their total on an hourly (or shorter) basis. In general, however, only the total solar radiation values were recorded. This report presents a correlation that relates the diffuse component of an hourly total solar radiation value to the total radiation ratio of the maximum value attainable. The data used were taken at the Blue Hill Observatory in Milton, Massachusetts, for the period 1952. The relation - in the form of the data plots - can be used in situations in which only the hourly total radiation data are available but the diffuse component is desired.

Author

**N77-21768\*** National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio.

### **ALL-WEATHER ICE INFORMATION SYSTEM FOR ALASKAN ARCTIC COASTAL SHIPPING**

R T Gedney, R. J. Jirberg, R. J. Schertler, R. A. Mueller, T. L. Chase, I. Kramarchuk, L. A. Nagy, R. A. Hanlon, and H. Mark 1977 14 p refs Presented at 9th Ann. Offshore Technology Conf., Houston, Tex., 2-5 May 1977 (NASA-TM-X-73619: E-9108) Avail: NTIS HC A02/MF A01 CSCI 04B

A near real-time ice information system designed to aid arctic coast shipping along the Alaskan North Slope is described. The system utilizes a X-band Side Looking Airborne Radar (SLAR) mounted aboard a U.S. Coast Guard HC-130B aircraft. Radar mapping procedures showing the type, areal distribution and concentration of ice cover were developed in order to guide vessel operational movements. Near real-time SLAR image data were transmitted directly from the SLAR aircraft to Barrow, Alaska and the U.S. Coast Guard icebreaker Glacier. In addition, SLAR image data were transmitted in real time to Cleveland, Ohio via the NOAA-GOES Satellite. Radar images developed in Cleveland were subsequently facsimile transmitted to the U.S. Navy's Fleet Weather Facility in Suitland, Maryland for use in ice forecasting and also as a demonstration back to Barrow via the Communications Technology Satellite.

Author

**A77-47961\*** All-weather ice information system for Alaskan Arctic coastal shipping. R. T. Gedney, R. J. Jirberg, R. J. Schertler, R. A. Mueller, T. L. Chase, I. Kramarchuk, L. A. Nagy, R. A. Hanlon, and H. Mark (NASA, Lewis Research Center, Cleveland, Ohio). *Annual Offshore Technology Conference, 9th, Houston, Tex., May 2-5, 1977, Paper.* 13 p. 7 refs.

## 52 AEROSPACE MEDICINE

Includes physiological factors, biological effects of radiation; and weightlessness.

**N77-11655\*** National Aeronautics and Space Administration, Lewis Research Center, Cleveland, Ohio.

### POTENTIAL BIOMEDICAL APPLICATIONS OF ION BEAM TECHNOLOGY

Bruce A. Banks, Albert J. Weigand, Charles A. Babbush (Mt. Sinai Hospital, Cleveland), and Craig L. VanKampen (Case Western Reserve Univ.) 1976 20 p refs Presented at the twelfth AIAA Intern. Elec Propulsion Conf., Key Biscayne, Fla., 15-17 Nov. 1976

(Grant GM-01090-14)

(NASA-TM-X-73512; E-8919) Avail: NTIS HC A02/MF A01 CSCL 06B

Electron bombardment ion thrusters used as ion sources have demonstrated a unique capability to vary the surface morphology of surgical implant materials. The microscopically rough surface texture produced by ion beam sputtering of these materials may result in improvements in the biological response and/or performance of implanted devices. Control of surface roughness may result in improved attachment of the implant to soft tissue, hard tissue, bone cement, or components deposited from blood. Potential biomedical applications of ion beam texturing discussed include: vascular prostheses, artificial heart pump diaphragms, pacemaker fixation, percutaneous connectors, orthopedic prosthesis fixation, and dental implants. Author

**N77-28716\*** National Aeronautics and Space Administration, Lewis Research Center, Cleveland, Ohio.

### CORNEAL SEAL DEVICE Patent

Edward F. Bashr, inventor (to NASA) issued 5 Jul. 1977 7 p Filed 13 Apr. 1976 Supersedes N76-22891 (14 - 13, p 1709)

(NASA-Case-LEW-12258-1; US-Patent-4,033,349;

US-Patent-Appl-SN-676433; US-Patent-Class-128-303R;

US-Patent-Class-128-1R) Avail: US Patent Office CSCL 06B

A corneal seal device is provided which, when placed in an incision in the eye, permits the insertion of a surgical tool or instrument through the device into the eye. The device includes a seal chamber which opens into a tube which is adapted to be sutured to the eye and serves as an entry passage for a tool. A sealable aperture in the chamber permits passage of the tool through the chamber into the tube and hence into the eye. The chamber includes inlet ports adapted to be connected to a regulated source of irrigation fluid which provides a safe intraocular pressure. Official Gazette of the U.S. Patent Office

**N77-30725\*** National Aeronautics and Space Administration, Lewis Research Center, Cleveland, Ohio.

### THE US ENVIRONMENTAL PROTECTION AGENCY NATIONAL POLLUTANT DISCHARGE ELIMINATION SYSTEM (NPDES)

Julian Manly Earls In its Proc. of the Ann. Conf. of NASA Clinic Directors, Environ. Health Off., and Med. Program Advisors 1975 p 167-176 refs (For primary document see N77-30715 21-52)

Avail: NTIS HC A13/MF A01 CSCL 06E

An evaluation of the Lewis Research Center's storm, sanitary and industrial sewer systems, in compliance with the Federal Water Pollution Control Act, is presented. The investigation of a proposed sampling and flow measurement system includes cost estimates to meet the Federal and State of Ohio requirements. I.M.

**N77-30736\*** National Aeronautics and Space Administration, Lewis Research Center, Cleveland, Ohio.

### INTRA-OCULAR PRESSURE NORMALIZATION APPARATUS Patent Application

Edward F. Bashr, inventor (to NASA) Filed 31 Aug. 1977 10 p

(NASA-Case-LEW-12955-1 US-Patent-Appl-SN-829318) Avail: NTIS HC A02/MF A01 CSCL 06B

A method and apparatus is described for safely reducing abnormally high intra-ocular pressure in an eye during a predetermined time interval. This allows maintenance of normal intraocular pressure during glaucoma surgery. A pressure regulator of the spring-biased diaphragm type is provided with additional bias by a column of liquid. The height of the column of liquid is selected such that the pressure at a hypodermic needle connected to the output of the pressure regulator is equal to the measured pressure of the eye. The hypodermic needle can then be safely inserted into the anterior chamber of the eye. Liquid is then bled out of the column to reduce the bias on the diaphragm of the pressure regulator and, consequently, the output pressure of the regulator. This lowering pressure of the regulator also occurs in the eye by means of a small bleed path provided between the pressure regulator and the hypodermic needle.

NASA

**N77-30737\*** National Aeronautics and Space Administration, Lewis Research Center, Cleveland, Ohio.

### INTRA-OCULAR PRESSURE NORMALIZATION TECHNIQUE AND EQUIPMENT Patent Application

William J. McGannon, inventor (to NASA) Filed 31 Aug. 1977 10 p Sponsored by NASA

(NASA-Case-LEW-12723-1; US-Patent-Appl-SN-829317) Avail: NTIS HC A02/MF A01 CSCL 06B

A method and apparatus is described for safely reducing abnormally high intraocular pressure in an eye during a predetermined time interval. This allows maintenance of normal intraocular pressure during glaucoma surgery. A pressure regulator of the spring-biased diaphragm type is provided with additional bias by a column of liquid. The height of the column of liquid is selected such that the pressure at a hypodermic needle connected to the output of the pressure regulator is equal to the measured pressure of the eye. The hypodermic needle can then be safely inserted into the anterior chamber of the eye. Liquid is then bled out of the column to reduce the bias on the diaphragm of the pressure regulator and, consequently, the output pressure of the regulator. This lowering pressure of the regulator also occurs in the eye by means of a small second bleed path provided between the pressure regulator and the hypodermic needle.

NASA

**53 BEHAVIORAL SCIENCES**

Includes psychological factors; individual and group behavior; crew training and evaluation; and psychiatric research.

**A77-13007 \* #** Potential biomedical applications of ion beam technology. B. A. Banks, A. J. Weigand (NASA, Lewis Research Center, Cleveland, Ohio), C. L. Van Kampen (Case-Western-Reserve University, Cleveland, Ohio), and C. A. Babbush. *American Institute of Aeronautics and Astronautics, International Electric Propulsion Conference, Key Biscayne, Fla., Nov. 14-17, 1976, Paper 76-1018.* 12 p. 15 refs. Grant No. PHS-5-T-01-GM-01090-14.

Electron bombardment ion thrusters used as ion sources have demonstrated a unique capability to vary the surface morphology of surgical implant materials. The microscopically rough surface texture produced by ion beam sputtering of these materials may result in improvements in the biological response and/or performance of implanted devices. Control of surface roughness may result in improved attachment of the implant to soft tissue, hard tissue, bone cement, or components deposited from blood. Potential biomedical applications of ion beam texturing discussed include: vascular prostheses, artificial heart pump diaphragms, pacemaker fixation, percutaneous connectors, orthopedic prosthesis fixation, and dental implants.

(Author)

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OF POOR QUALITY

## **54 MAN/SYSTEM TECHNOLOGY AND LIFE SUPPORT**

Includes human engineering; biotechnology; and space suits and protective clothing.

**N77-29770\*** Martin Marietta Corp., Denver, Colo.

### **THE ASSEMBLY OF LARGE STRUCTURES IN SPACE**

George W. Smith and Shepard B. Brodie /in JPL The 2nd Conf. on Remotely Manned Systems (RMS) Jun. 1975 p 43-44 (For primary document see N77-29750 20-54)

Contracts NAS9-14319; NAS3-17835

Avail: NTIS HC A06/MF A01 CSCL 05H

Techniques developed for orbital assembly of the support structure for a 1000 meter diameter microwave power transmission system antenna are described. The operation is performed in two phases using the shuttle remote manipulator system in low earth orbit, and a mobile assembler in geosynchronous orbit.

Author

## 61 COMPUTER PROGRAMMING AND SOFTWARE

Includes computer programs, routines, and algorithms.

**N77-10810\*** National Aeronautics and Space Administration, Lewis Research Center, Cleveland, Ohio

### **GASLOT: A COMPUTER PROGRAM FOR RAPID PRODUCTION OF THERMOPHYSICAL PROPERTIES CHARTS FOR CYCLE ANALYSIS AND PROPERTY EVALUATIONS**

R. C. Hendricks and R. J. Trivisonno 1976 23 p refs. Proposed for presentation at Winter Ann. Meeting of the Am. Soc. of Mechanical Engineers, New York, 5-10 Dec 1976 (NASA-TM-X-71915; E-8707) Avail: NTIS HC A02/MF A01

GASLOT is a FORTRAN 5 computer program which slaves a CALCOMP plotter to produce a variety of accurate thermophysical properties charts. The ordinate-abscissa pair may be any two of pressure, temperature, density, enthalpy, entropy, specific heat, sonic velocity, thermal conductivity, viscosity, or surface tension. The parameters may be temperature, pressure, density, entropy or enthalpy. A special feature of this program is the ability to produce a chart which amplifies (or reduces) a given chart to achieve the desired resolution. Author

**N77-11718\*** National Aeronautics and Space Administration, Lewis Research Center, Cleveland, Ohio

### **CENTROID AND MOMENTS OF AN AREA USING A DIGITIZER**

R. W. Patch Oct 1976 19 p refs (NASA-TM-X-73528; E-8947) Avail: NTIS HC A02/MF A01 CSDL 09B

The centroid and moments of an area program provides the centroid, moments of inertia, product of inertia, radii of gyration, and area of any closed planar geometric figure. The figure must be available in graphic form and is digitized once with chart digitizer (graphic tablet). The digitizer origin may be set anywhere on the digitizer table. After digitizing, fifteen quantities are calculated and displayed: (1) area, (2) moment of inertia of area with respect to digitizer x-axis, (3) moment of inertia of area with respect to digitizer y-axis, (4) product of inertia of area with respect to digitizer axes, (5) first moment of x for digitizer axes, (6) first moment of y for digitizer axes, (7) x-coordinate of centroid, (8) y-coordinate of centroid, (9) moment of area inertia of with respect to x-axis through centroid, (10) moment of inertia of area with respect to y-axis through centroid, (11) product inertia of area with respect to x and y axes through centroid, (12) polar moment of inertia of area around centroid, (13) radius of gyration about digitizer x-axis, (14) radius of gyration about digitizer y-axis, and (15) variance in the x-direction. Author

**N77-19775\*** National Aeronautics and Space Administration, Lewis Research Center, Cleveland, Ohio

### **A PDP-15 TO INDUSTRIAL-14 INTERFACE AT THE LEWIS RESEARCH CENTER'S CYCLOTRON**

Francis R. Kebberly and Regis F. Leonard Mar. 1977 21 p refs (NASA-TM-X-73604; E-9077) Avail: NTIS HC A02/MF A01 CSDL 09B

An interface (hardware and software) was built which permits the loading, monitoring, and control of a digital equipment industrial-14/30 programmable controller by a PDP-15 computer. The interface utilizes the serial mode for data transfer to and from the controller, so that the required hardware is essentially that of a teletype unit except for the speed of transmission. Software described here permits the user to load binary paper tape, read or load individual controller memory locations, and if desired turn controller outputs on and off directly from the computer. Author

**N77-22848\*** National Aeronautics and Space Administration, Lewis Research Center, Cleveland, Ohio

### **SAVLOC, COMPUTER PROGRAM FOR AUTOMATIC CONTROL AND ANALYSIS OF X-RAY FLUORESCENCE EXPERIMENTS**

Regis F. Leonard Washington Apr. 1977 45 p refs (NASA-TN-D-8398; E-9000) Avail: NTIS HC A03/MF A01 CSDL 09B

A program for a PDP-15 computer is presented which provides for control and analysis of trace element determinations by using X-ray fluorescence. The program simultaneously handles data accumulation for one sample and analysis of data from previous samples. Data accumulation consists of sample changing, timing, and data storage. Analysis requires the locating of peaks in X-ray spectra, determination of intensities of peaks, identification of origins of peaks, and determination of a real density of the element responsible for each peak. The program may be run in either a manual (supervised) mode or an automatic (unsupervised) mode. Author

**N77-26829\*** National Aeronautics and Space Administration, Lewis Research Center, Cleveland, Ohio

### **SOLUTION OF TRANSIENT OPTIMIZATION PROBLEMS BY USING AN ALGORITHM BASED ON NONLINEAR PROGRAMMING**

Fred Teren 1977 13 p refs. Presented at Joint Autom. Control Conf., San Francisco, 22-24 Jun. 1977 (NASA-TM-X-73618; E-9107) Avail: NTIS HC A02/MF A01 CSDL 09B

An algorithm is presented for solution of dynamic optimization problems which are nonlinear in the state variables and linear in the control variables. It is shown that the optimal control is bang-bang. A nominal bang-bang solution is found which satisfies the system equations and constraints, and influence functions are generated which check the optimality of the solution. Nonlinear optimization (gradient search) techniques are used to find the optimal solution. The algorithm is used to find a minimum time acceleration for a turbofan engine. Author

**N77-27751\*** National Aeronautics and Space Administration, Lewis Research Center, Cleveland, Ohio

### **COMPUTER PROGRAM FOR FLAT SECTOR THRUST BEARING PERFORMANCE**

Alden F. Presler and Izhak Etsion Jun. 1977 74 p refs (NASA-TM-73595; E-8930) Avail: NTIS HC A04/MF A01 CSDL 09B

A versatile computer program is presented which achieves a rapid, numerical solution of the Reynolds equation for a flat sector thrust pad bearing with either compressible or liquid lubricants. Program input includes a range in values of the geometric and operating parameters of the sector bearing. Performance characteristics are obtained from the calculated bearing pressure distribution. These are the load capacity, center of pressure coordinates, frictional energy dissipation, and flow rates of liquid lubricant across the bearing edges. Two sample problems are described. Author

**N77-28831\*** National Aeronautics and Space Administration, Lewis Research Center, Cleveland, Ohio

### **COMPUTER PROGRAMS FOR THE INTERPRETATION OF LOW RESOLUTION MASS SPECTRA: PROGRAM FOR CALCULATION OF MOLECULAR ISOTOPIC DISTRIBUTION AND PROGRAM FOR ASSIGNMENT OF MOLECULAR FORMULAS**

Robert A. Miller and Fred J. Kohl Washington Jul 1977 18 p refs (NASA-TM-X-3564; E-9133) Avail: NTIS HC A02/MF A01 CSDL 09B

Two FORTRAN computer programs for the interpretation of low resolution mass spectra were prepared and tested. One is for the calculation of the molecular isotopic distribution of any species from stored elemental distributions. The program requires only the input of the molecular formula and was designed for

compatibility with any computer system. The other program is for the determination of all possible combinations of atoms (and radicals) which may form an ion having a particular integer mass. It also uses a simplified input scheme and was designed for compatibility with any system.

Author

**N77-28832\*** National Aeronautics and Space Administration  
Lewis Research Center, Cleveland, Ohio.

**FLUID: A NUMERICAL INTERPOLATION PROCEDURE FOR  
OBTAINING THERMODYNAMIC AND TRANSPORT  
PROPERTIES OF FLUIDS**

Theodore E. Fessler. Washington. Aug. 1977. 27 p. refs.  
(NASA-TM-X-3572; E-9132) Avail. NTIS HC A03/MF A01  
CSCL 09B

A computer program subroutine, FLUID, was developed to calculate thermodynamic and transport properties of pure fluid substances. It provides for determining the thermodynamic state from assigned values for temperature-density, pressure-density, temperature-pressure, pressure-entropy, or pressure-enthalpy. Liquid or two-phase (liquid-gas) conditions are considered as well as the gas phase. A van der Waals model is used to obtain approximate state values; these values are then corrected for real gas effects by model-correction factors obtained from tables based on experimental data. Saturation conditions, specific heat, entropy, and enthalpy data are included in the tables for each gas. Since these tables are external to the FLUID subroutine itself, FLUID can implement any gas for which a set of tables has been generated. (A setup phase is used to establish pointers dynamically to the tables for a specific gas.) Data-table preparation is described. FLUID is available in both SFTRAN and FORTRAN.

Author



## 65 STATISTICS AND PROBABILITY

Includes data sampling and smoothing, Monte Carlo method, and stochastic processes.

**N77-33929\*** National Aeronautics and Space Administration  
Lewis Research Center, Cleveland, Ohio

### **A WEIBULL CHARACTERIZATION FOR TENSILE FRACTURE OF MULTICOMPONENT BRITTLE FIBERS**

R. G. Barrows 1977 30 p refs Presented at the Fall Metals Conf., Chicago, 24-27 Oct 1977, sponsored by the Met. Soc. of the Am. Inst. of Mining, Met., and Petrol. Engr. Prepared in cooperation with US Army Air Mobility R and D Lab., Cleveland

(NASA TM-73790, E-9357) Avail: NTIS HC A03/MF A01  
CSCL 12A

A statistical characterization for multicomponent brittle fibers is presented. The method, which is an extension of usual Weibull distribution procedures, statistically considers the components making up a fiber (e.g., substrate, sheath, and surface) as separate entities and taken together as in a fiber. Tensile data for silicon carbide fiber and for an experimental carbon-boron alloy fiber are evaluated in terms of the proposed multicomponent Weibull characterization.

Author

## 66 SYSTEMS ANALYSIS

Includes mathematical modeling, network analysis, and operations research.

**N77-17815\*** National Aeronautics and Space Administration, Lewis Research Center, Cleveland, Ohio.

### **PRESSURE MODEL OF A FOUR-WAY SPOOL VALVE FOR SIMULATING ELECTROHYDRAULIC CONTROL SYSTEMS**

Vernon D. Gebben Washington Dec. 1976 33 p refs  
(NASA-TN-D-8306; E-8820) Avail: NTIS HC A03/MF A01  
CSCL 12B

An equation that relates the pressure flow characteristics of hydraulic spool valves was developed. The dependent variable is valve output pressure, and the independent variables are spool position and flow. This causal form of equation is preferred in applications that simulate the effects of hydraulic line dynamics. Results from this equation are compared with those from the conventional valve equation, whose dependent variable is flow. A computer program of the valve equations includes spool stops, leakage spool clearances, and dead-zone characteristics of overlap spools

Author

**N77-17820\*** National Aeronautics and Space Administration, Lewis Research Center, Cleveland, Ohio.

### **SPACECRAFT DESIGN SENSITIVITY FOR A DISASTER WARNING SATELLITE SYSTEM**

Joseph E. Maloy, Charles E. Provencher, Bruce E. LeRoy, Richard C. Braley, and Howard A. Shumaker Washington Feb. 1977  
45 p refs  
(NASA-TM-X-3469; E-8856) Avail: NTIS HC A03/MF A01  
CSCL 12B

A disaster warning satellite (DWS) is described for warning the general public of impending natural catastrophes. The concept is responsive to NOAA requirements and maximizes the use of ATS-6 technology. Upon completion of concept development, the study was extended to establishing the sensitivity of the DWSS spacecraft power, weight, and cost to variations in both warning and conventional communications functions. The results of this sensitivity analysis are presented.

Author

## 70 PHYSICS (GENERAL)

For geophysics see 46 Geophysics. For astrophysics see 90 Astrophysics. For solar physics see 92 Solar physics.

**A77-13006 \*** A 30-cm diameter argon ion source. J. S. Sovey (NASA, Lewis Research Center, Cleveland, Ohio). *American Institute of Aeronautics and Astronautics, International Electric Propulsion Conference, Key Biscayne, Fla., Nov. 14-17, 1976, Paper 76-1017*. 10 p. 12 refs.

A 30-cm diameter argon ion source was evaluated. Ion source beam currents up to 4A were extracted with ion energies ranging from 0.2 to 1.5 KeV. An ion optics scaling relation was developed for predicting ion beam extraction capability as a function of total extraction voltage, gas type and screen grid open area. Ignition and emission characteristics of several hollow cathode geometries were assessed for purposes of defining discharge chamber and neutralizer cathodes. Also presented are ion beam profile characteristics which exhibit broad beam capability well suited for ion beam sputtering applications.

(Author)

**A77-47895 \*** Absorption of sound in air - High-frequency measurements. H. E. Bass and F. D. Shields (Mississippi, University, University, Miss.). *Acoustical Society of America, Journal*, vol. 62, Sept. 1977, p. 571-576. 35 refs. Contract No. NAS3-19431.

The absorption of sound in air at frequencies from 4 to 100 kHz in 1/12 octave intervals, for temperatures from 255.4 K (0 F) to 310.9 K (100 F) in 5.5 K (10 F) intervals, and at 10% relative humidity increments between 0% and saturation has been measured. The values of free-field absorption have been analyzed to determine the relaxation frequency of oxygen for each of the 92 combinations of temperature and relative humidity studied and the results are compared to an empirical expression. The relaxation frequencies of oxygen have been analyzed to determine the microscopic energy transfer rates.

(Author)

## 71 ACOUSTICS

Includes sound generation, transmission and attenuation.

For noise pollution see 45 Environment Pollution

**N77-11815\*** National Aeronautics and Space Administration, Lewis Research Center, Cleveland, Ohio.

### OTW NOISE CORRELATION FOR SEVERAL NOZZLE/WING GEOMETRIES USING A 5:1 SLOT NOZZLE WITH EXTERNAL DEFLECTORS

U. VonGlabn 1976 28 p refs Presented at the 92nd Meeting of the Acoustical Soc. of Am., San Diego, Calif., 16-19 Nov. 1976

(NASA-TM-X-73529; E-8949) Avail: NTIS HC A03/MF A01 CSCL 20A

Acoustic spectral data obtained from a model-scale study of several over the wing (OTW) configurations with a 5:1 slot nozzle using various external deflectors are correlated in terms of deflector geometry and flow parameters. Variations in the deflector geometry include deflector size and deflector angle. In addition, geometry variations in flap setting and nozzle chordwise location are included. Three dominant noise sources are correlated: fluctuating lift noise, flap trailing edge noise, and jet mixing noise. Aerodynamic characteristics including lift and thrust measurements, obtained for the various configurations are summarized. Author

**N77-11817\*** National Aeronautics and Space Administration, Lewis Research Center, Cleveland, Ohio.

### MODAL DENSITY FUNCTION AND NUMBER OF PROPAGATING MODES IN DUCTS

E. J. Rice 1976 19 p refs Presented at the 92d Meeting of the Acoust. Soc. of Am., San Diego, Calif., 16-19 Nov 1976 (NASA-TM-X-73539; E-8699) Avail: NTIS HC A02/MF A01 CSCL 20A

The question of the number of propagating modes within a small range of mode cut off ratio was raised. The population density of modes were shown to be greatest near cut off and least for the well propagating modes. It was shown that modes of nearly the same cut off ratio behave nearly the same in a sound absorbing duct as well as in the way they propagate to the far. Handling all of the propagating modes individually, they can be grouped into several cut off ratio ranges. It is important to know the modal density function to estimate acoustic power distribution. Author

**N77-13792\*** National Aeronautics and Space Administration, Lewis Research Center, Cleveland, Ohio.

### ACOUSTIC SIGNATURES OF A MODEL FAN IN THE NASA-LEWIS ANECHOIC WIND TUNNEL

Donald A. Dietrich, Marcus F. Heidmann, and John M. Abbott 26 Jan. 1977 17 p refs Presented at the 15th Aerospace Scis. Meeting, Los Angeles, 24-26 Jan. 1977. Sponsored by AIAA

(NASA-TM-X-73560; E-9002) Avail: NTIS HC A02/MF A01 CSCL 20A

One-third octave band and narrowband spectra and continuous directivity patterns radiated from an inlet are presented over ranges of fan operating conditions, tunnel velocity, and angle of attack. Tunnel flow markedly reduced the unsteadiness and level of the blade passage tone, revealed the cutoff design feature of the blade passage tone, and exposed a lobular directivity pattern for the second harmonic tone. The full effects of tunnel flow are shown to be complete above a tunnel velocity of 20 meters/second. The acoustic signatures are also shown to be strongly affected by fan rotational speed, fan blade loading, and inlet angle of attack. Author

**N77-30908\*** National Aeronautics and Space Administration, Lewis Research Center, Cleveland, Ohio.

### FINITE-DIFFERENCE THEORY FOR SOUND PROPAGATION IN A LINED DUCT WITH UNIFORM FLOW USING THE WAVE ENVELOPE CONCEPT

Kenneth J. Baumeister Washington Aug 1977 64 p refs (NASA-TP-1001; E-9149) Avail: NTIS HC A04/MF A01 CSCL 20A

Finite difference equations are derived for sound propagation in a two dimensional, straight soft wall duct with a uniform flow by using the wave envelope concept. This concept reduces the required number of finite difference grid points by one to two orders of magnitude depending on the length of the duct and the frequency of the sound. The governing acoustic difference equations in complex notation are derived. An exit condition is developed that allows a duct of finite length to simulate the wave propagation in an infinitely long duct. Sample calculations presented for a plane wave incident upon the acoustic liner show the numerical theory to be in good agreement with closed form analytical theory. Complete pressure and velocity printouts are given to some sample problems and can be used to debug and check future computer programs. Author

**N77-32836\*** National Aeronautics and Space Administration, Lewis Research Center, Cleveland, Ohio.

### INLET TURBULENCE AND FAN NOISE MEASURED IN AN ANECHOIC WIND TUNNEL AND STATICALLY WITH AN INLET FLOW CONTROL DEVICE

Loretta M. Shaw, Richard P. Woodward, Frederick W. Glaser, and Benjamin J. Dastoli Oct 1977 28 p refs Presented at 4th Aeroacoustic Conf., Atlanta, 3-5 Oct. 1977, sponsored by AIAA

(NASA-TM-73723; E-9273) Avail: NTIS CSCL 20A

Turbulence and acoustic measurements were taken in a wind tunnel which has demonstrated blade passage tone cutoff phenomena with forward velocity. Turbulence data were taken in a subsonic inlet at various fan speeds under static and forward velocity conditions. A honeycomb/screen flow control device was placed over the inlet during static tests to modify the inflow in an attempt to simulate flight conditions. Acoustic levels of the blade passage tone along with transverse turbulence intensities were reduced with forward velocity. The flow control device reduced the blade passage tone to an intermediate level between those levels associated with static and forward velocity operation. Author

**N77-32837\*** National Aeronautics and Space Administration, Lewis Research Center, Cleveland, Ohio.

### AEROACOUSTIC PERFORMANCE OF A SCOOP INLET

John M. Abbott Oct 1977 14 p refs Presented at the 4th Aeroacoustics Conf., Atlanta, 3-5 Oct. 1977

(NASA-TM-73725; E-9277) Avail: NTIS HC A02/MF A01 CSCL 20A

A low speed wind tunnel test demonstrated the aerodynamic and acoustic performance of a scoop inlet. Engine noise is directed upward by the extended lower lip of the scoop inlet. In addition, more of the scoop airflow comes in from above the inlet than below, leading to relatively higher surface velocities on the upper lip and lower surface velocities on the lower lip. These lower velocities on the lower lip result in a higher attainable angle of attack before internal flow separation occurs. Author

**N77-32838\*** National Aeronautics and Space Administration, Lewis Research Center, Cleveland, Ohio.

### INTERIM NOISE CORRELATION FOR SOME OTW CONFIGURATIONS USING EXTERNAL JET-FLOW DEFLECTORS

U. VonGlabn and D. Groesbeck Oct. 1977 27 p refs Presented at the 4th Aeroacoustics Conf., Atlanta, 3-5 Oct. 1977, sponsored by AIAA

(NASA-TM-73746; E-9317) Avail: NTIS HC A03/MF A01 CSCL 20A

Jet flap interaction acoustic data obtained statically from a model-scale study of STOL-OTW configurations with a conical

nozzle mounted above the wing and using various external deflectors to provide jet-flow attachment are correlated. The acoustic data are correlated in terms that consider the jet/flap interaction noise contributions associated primarily with fluctuating lift, trailing edge, and configuration wake noise sources. Variables considered include deflector geometry, flap setting and wing size. Finally, the configuration overall noise levels are related to static lift and thrust measurements in order to provide insight into possible acoustic/aerodynamic performance trade-off benefits.

Author

**A77-17066 \* #** A theoretical study of the acoustic impedance of orifices in the presence of a steady grazing flow. E. J. Rice (NASA, Lewis Research Center, Cleveland, Ohio). *Acoustical Society of America, Annual Meeting, 91st, Washington, D.C., Apr. 5-9, 1976, Paper. 22 p. 18 refs.*

Oscillatory fluid flow in the vicinity of a circular orifice with a steady grazing flow is analyzed. A simplified system of partial differential equations is obtained by starting with the momentum and continuity equations and by assuming that the flow can be represented as an oscillatory motion superimposed on the (known) steady flow. It is found that the equations are linear in the region where grazing-flow effects dominate; a solution and the resultant orifice impedance are given for this region. It is tentatively concluded that orifice resistance is directly proportional to grazing-flow velocity and that the orifice inductive end correction is not a function of grazing flow.

F.G.M.

**DATA SUMMARY:** Comparison of measured and theoretical static pressures near an orifice for both upstream and downstream pressure taps are included; variables are measured static pressure, theoretical static pressure, normalized pressure difference, orifice velocity, grazing flow velocity; one figure includes numeric data.

**A77-19829 \* #** Inlet total pressure loss due to acoustic wall treatment. B. A. Miller (NASA, Lewis Research Center, Aeronautics Directorate, Cleveland, Ohio). *American Institute of Aeronautics and Astronautics, Aerospace Sciences Meeting, 15th, Los Angeles, Calif., Jan. 24-26, 1977, Paper 77-105. 12 p. 7 refs.*

Experimental determination of the effect of diffuser wall acoustic treatment on inlet total pressure loss. Data were obtained by testing an inlet model with 10 different acoustically treated diffusers differing only in the design of the Helmholtz resonator acoustic treatment. Tests were conducted in a wind tunnel at forward velocities to 41 meters per second for inlet throat Mach numbers of .5 to .8 and angles of attack as high as 50 degrees. Results indicate a pressure loss penalty due to acoustic treatment that increases linearly with the porosity of the acoustic facing sheet. For a surface porosity of 14% the total pressure loss was 21% greater than that for an untreated inlet. The penalty resulting from treatment increased for average throat Mach numbers above approximately .7 where local regions of sonic or supersonic surface flow were encountered. Pressure loss over the treatment was not affected by the presence of noise.

(Author)

**DATA SUMMARY:** Diverse data are presented; variables include surface Mach number, average throat Mach number, pressure loss coefficient, pressure recovery, sound pressure reduction, surface porosity, fraction of passage height measured from windward tip, angle of attack at flow separation, facing sheet porosity, and honeycomb depth; 12 figures and two tables include numeric data.

**A77-31446 \*** Aeroacoustics. M. E. Goldstein (NASA, Lewis Research Center, Cleveland, Ohio). New York, McGraw-Hill International Book Co., 1976. 305 p. 202 refs. \$29.

A review of the acoustics of moving media is provided, taking into account a derivation of basic equations, wave-like solutions of acoustic equations, the solutions of acoustic equations by superposition of elementary sources, the source distribution in unbounded regions, the radiation field, energy relations, and moving sound sources. The characteristics of aerodynamic sound are considered along with the effect of solid boundaries, the effect of uniform flow,

acoustic field equations, and the effects of nonuniform mean flow on the generation of sound. Attention is given to Lighthill's acoustic analogy, the solution of Lighthill's equation when no solid boundaries are present, the application of Lighthill's theory to turbulent flows, and the physics of jet noise.

G.R.

**A77-44459 \* #** Modal density function and number of propagating modes in ducts. E. J. Rice (NASA, Lewis Research Center, Cleveland, Ohio). *Acoustical Society of America, Meeting, 92nd, San Diego, Calif., Nov. 16-19, 1976, Paper. 19 p. 8 refs.*

Often raised questions in duct sound propagation studies involve the total number of propagating modes, the number of propagating radial modes for a particular spinning lobe number, and the number of modes possible between two given values of cutoff ratio or eigenvalue. These questions can be answered approximately by using the modal distribution function which is the integral of the modal density function for ducts in a manner similar to that previously published for architectural acoustics. The modal density functions are derived for rectangular and circular ducts with a uniform steady flow. Results from this continuous theory are compared to the actual (discrete) modal distributions.

(Author)

**A77-44461 \* #** OTW noise correlation for several nozzle/wing geometries using a 5:1 slot nozzle with external deflectors. U. von Glahn and D. Groesbeck (NASA, Lewis Research Center, Cleveland, Ohio). *Acoustical Society of America, Meeting, 92nd, San Diego, Calif., Nov. 16-19, 1976, Paper. 28 p. 9 refs.*

Acoustic spectral data obtained from a model-scale study of several OTW configurations with a 5:1 slot nozzle using various external deflectors are correlated in terms of deflector geometry and flow parameters. Variations in the deflector geometry include deflector size and deflector angle. In addition, geometry variations in flap setting and nozzle chordwise location are included. Three dominant noise sources are correlated: fluctuating lift noise, flap trailing edge noise, and jet mixing noise. Aerodynamic characteristics, including lift and thrust measurements, obtained for the various configurations are summarized.

(Author)

**A77-51042 \* #** Multimodal far-field acoustic radiation pattern - An approximate equation. E. J. Rice (NASA, Lewis Research Center, Cleveland, Ohio). *American Institute of Aeronautics and Astronautics, Aeroacoustics Conference, 4th, Atlanta, Ga., Oct. 3-5, 1977, Paper 77-1281. 9 p. 14 refs.*

The far-field sound radiation theory for a circular duct was studied for both single mode and multimodal inputs. The investigation was intended to develop a method to determine the acoustic power produced by turbofans as a function of mode cut-off ratio. This information is essential for the design of acoustic suppressors in engine ducts. With reasonable simplifying assumptions the single mode radiation pattern was shown to be reducible to a function of mode cut-off ratio only (modal indices removed). With modal cut-off ratio as the dominant variable, multimodal radiation patterns can be reduced to a simple explicit expression. This approximate expression provides excellent agreement with an exact calculation of the sound radiation pattern using equal acoustic power per mode. Radiation patterns for cases other than equal modal power are presented using the approximate radiation equation. An approximate expression for the duct termination losses as a function of cut-off ratio is also included.

(Author)

**A77-51095 \* #** Interaction of rotor tip flow irregularities with stator vanes as a noise source. J. H. Dittmar (NASA, Lewis Research Center, Cleveland, Ohio). *American Institute of Aeronautics and Astronautics, Aeroacoustics Conference, 4th, Atlanta, Ga., Oct. 3-5, 1977, Paper 77-1342. 10 p. 27 refs.*

The role of the interaction of rotor tip flow irregularities (vortices and velocity defects) with downstream stator vanes is

discussed as a possible fan noise mechanism. This is accomplished by: indicating some of the methods of formation of these flow irregularities; observing how they would behave with respect to known noise behavior and; attempting to compare the strength of the rotor tip flow irregularity mechanism with the strength of the more common rotor wake-stator mechanism. The rotor tip flow irregularity-stator interaction is indicated as being a probable inflight noise source. (Author)

**A77-51107 \*** # Aeroacoustic performance of a scoop inlet. J. M. Abbott (NASA, Lewis Research Center, Cleveland, Ohio). *American Institute of Aeronautics and Astronautics, Aeroacoustics Conference, 4th, Atlanta, Ga., Oct. 3-5, 1977, Paper 77-1354*. 10 p. 10 refs.

Results of a low speed wind tunnel test program are presented which demonstrate the aerodynamic and acoustic performance of a scoop inlet. Engine noise that would normally propagate toward the ground is directed upward by the extended lower lip of the scoop inlet. In addition, more of the scoop airflow comes in from above the inlet than below, leading to relatively higher surface velocities on the upper lip and lower surface velocities on the lower lip. These lower velocities on the lower lip result in a higher attainable angle of attack before internal flow separation occurs. (Author)

**N77-15792\*** # Hersh Acoustical Engineering, Chatsworth, Calif. **SOUND PROPAGATION IN CHOKED DUCTS** Final Contractor Report

Alan S. Hersh and C. Y. Liu Dec. 1976 44 p refs (Contract NAS3-18556)

(NASA-CR-135123) Avail: NTIS HC A03/MF A01 CSCL 20A

The linearized equations describing the propagation of sound in variable area ducts containing flow are shown to be singular when the duct mean flow is sonic. The singularity is removed when previously ignored nonlinear terms are retained. The results of a numerical study, for the case of plane waves propagating in a one-dimensional converging-diverging duct, show that the sound field is adequately described by the linearized equations only when the axial mean flow Mach number at the duct throat  $M_{sub\ th} < 0.6$ . For  $M_{sub\ th} > 0.6$ , the numerical results showed that acoustic energy flux was not conserved. An attempt was made to extend the study to include the nonlinear behavior of the sound field. Meaningful results were not obtained due, primarily, to numerical difficulties. Author

**DATA SUMMARY:** Results of numerical analyses of sound propagation in ducts; variables include Mach number, sound reflection coefficient, sound transmission; 6 figures include numeric data.

**N77-18879\*** # AiResearch Mfg. Co., Phoenix, Ariz. **ADVANCED ACOUSTIC AND AERODYNAMIC 20-INCH FAN PROGRAM** Final Report

J. R. Erwin and R. W. Heldenbrand 15 Dec. 1977 94 p refs (Contract NAS3-18533)

(NASA-CR-135093; AiResearch-75-211789) Avail: NTIS HC A05/MF A01 CSCL 20A

The aerodynamic analyses, mechanical analyses, and stress tests of a 20-inch diameter advanced fan design intended for acoustic investigation by NASA-LaRC are discussed. A high tip speed transonic fan rotor was scaled directly to 20.0 inches (0.508 m) from a 28.74-inch (0.73-m) diameter rotor. A new stator was designed and fabricated for the fan and incorporated with a test rig housing and adapter hardware for installation in the NASA-LaRC Jet Noise Facility for acoustic evaluation. The stator was designed to allow mounting at three axial locations, and the fan, housing, and adapters are reversible so that either the inlet or the exhaust ends of the assembly face the open room of the test facility. Excellent aerodynamic performance is predicted, and a low noise signature is expected since the unique aerodynamic design features of this fan are directly conducive to producing minimum sound power. Author

**DATA SUMMARY:** Diverse data are presented; variables include weight, moments of inertia, stresses, strain, radius, angles, frequency, speed, torsional flutter parameter, Mach number.

**N77-28910\*** # Mississippi Univ., University. **ATMOSPHERIC ABSORPTION OF HIGH FREQUENCY NOISE AND APPLICATION TO FRACTIONAL-OCTAVE BANDS** Final Report

F. Douglas Shields and H. E. Bass Washington NASA Jun. 1977 239 p refs

(Contract NAS3-19431)

(NASA-CR-2760) Avail: NTIS HC A11/MF A01 CSCL 20A

Pure tone sound absorption coefficients were measured at 1/12 octave intervals from 4 to 100 KHz at 5.5K temperature intervals between 255.4 and 310.9 K and at 10 percent relative humidity increments between 0 percent and saturation in a large cylindrical tube (i.d., 25.4 cm; length, 4.8 m). Special solid-dielectric capacitance transducers, one to generate bursts of sound waves and one to terminate the sound path and detect the tone bursts, were constructed to fit inside the tube. The absorption was measured by varying the transmitter receiver separation from 1 to 4 m and observing the decay of multiple reflections or change in amplitude of the first received burst. The resulting absorption was compared with that from a proposed procedure for computing sound absorption in still air. Absorption of bands of noise was numerically computed by using the pure tone results. The results depended on spectrum shape, on filter type, and nonlinearly on propagation distance. For some of the cases considered, comparison with the extrapolation of ARP-866A showed a difference as large as a factor of 2. However, for many cases, the absorption for a finite band was nearly equal to the pure tone absorption at the center frequency of the band. A recommended prediction procedure is described for 1/3 octave band absorption coefficients. Author

**N77-32836\*** # Hersh Acoustical Engineering, Chatsworth, Calif. **FLUID MECHANICAL MODEL OF THE HELMHOLTZ RESONATOR** Final Report

Alan S. Hersh and Bruce Walker Washington NASA Sep 1977 74 p refs

(Contract NAS3-18542)

(NASA-CR-2904) Avail: NTIS HC A04/MF A01 CSCL 20A

A semi-empirical fluid mechanical model of the acoustic behavior of Helmholtz resonators is presented which predicts impedance as a function of the amplitude and frequency of the incident sound pressure field and resonator geometry. The model assumes that the particle velocity approaches the orifice in a spherical manner. The incident and cavity sound fields are connected by solving the governing oscillating mass and momentum conservation equations. The model is in agreement with the Rayleigh slug-mass model at low values of incident sound pressure level. At high values, resistance is predicted to be independent of frequency, proportional to the square root of the amplitude of the incident sound pressure field, and virtually independent of resonator geometry. Reactance is predicted to depend in a very complicated way upon resonator geometry, incident sound pressure level, and frequency. Nondimensional parameters are defined that divide resonator impedance into three categories corresponding to low, moderately low, and intense incident sound pressure amplitudes. The two-microphone method was used to measure the impedance of a variety of resonators. The data were used to refine and verify the model. Author

**A77-19780 \*** # Increase in effectiveness of low frequency acoustic liners by use of coupled Helmholtz resonators. L. W. Dean (United Technologies Corp., Pratt and Whitney Aircraft Group, East Hartford, Conn.). *American Institute of Aeronautics and Astronautics, Aerospace Sciences Meeting, 15th, Los Angeles, Calif., Jan. 24-26, 1977, Paper 77-19*. 9 p. 14 refs. Contract No. NAS3-18552.

Coupling of Helmholtz resonators in a low-frequency absorber array was studied as a means for increasing the effectiveness for absorbing low-frequency core engine noise. The equations for the impedance of the coupled-resonator systems were developed in terms

of uncoupled-resonator parameters, and the predicted impedance for a parallel-coupled scheme is shown to compare favorably with measurements from a test model. In addition, attenuation measurements made in a flow duct on test coupled-resonator panels are shown to compare favorably with predicted values. Finally, the parallel-coupled concept is shown to give significantly more attenuation than that of a typical uncoupled resonator array of the same total volume. (Author)

**DATA SUMMARY:** Diverse data are presented; variables include acoustic frequency, specific resistance, specific reactance, attenuation, third-octave-band center frequency, resonator neck diameter, neck length, cavity volume, surface area, analogous resistance; ten figures and three tables include numeric data.

**A77-44494 \*** Tube method of sound-absorption measurement extended to frequencies far above cutoff. F. D. Shields, H. E. Bass, and L. N. Bolen (Mississippi, University, University, Miss.). *Acoustical Society of America, Journal*, vol. 62, Aug. 1977, p. 346-353. 9 refs. Contract No. NAS3-19431.

Equipment had been constructed for measuring sound absorption in the frequency range from 4 to 100 kHz in a large tube 25.4 cm in diameter and 4.8 m long. The technique employs a large moveable solid dielectric capacitance transducer that completely fills the tube cross section and generates pulses of plane waves. An identical transducer terminates the other end of the tube and serves as a microphone to detect and reflect the sound pulses. Measurements in argon, nitrogen, and air indicate that the attenuation of the sound pulses differs by less than 1% from values calculated for the zero-order mode for frequencies up to 44 times the cutoff frequency for the first 'nonplane' mode. Above that frequency, the measured values are less than those predicted by theory by an amount that is approximately proportional to the wavelength to the 3.1 power. In a smaller tube of similar construction, the high-frequency deviation from theory is absent. (Author)

**A77-51030 \* #** An experimental study of transmission, reflection and scattering of sound in a free-jet flight simulation facility and comparison with theory. K. K. Ahuja, B. J. Tester, H. K. Tanna, and N. Searle (Lockheed-Georgia Co., Marietta, Ga.). *American Institute of Aeronautics and Astronautics, Aerodynamics Conference, 4th, Atlanta, Ga., Oct. 3-5, 1977, Paper 77-1266*. 17 p. 6 refs. Contract No. NAS3-20050.

Acoustic time delays across a free-jet shear layer are measured and compared with predictions based on (1) ray paths refracted abruptly across a cylindrical vortex sheet and (2) ray paths traced through a more realistic diverging flow model. The close agreement between measurement and theory confirms that Snell's law provides an accurate prediction of wavefront refraction or angle changes across a diverging shear layer. Microphones are placed on calculated ray paths to determine the coherent transmission and internal reflection characteristics of the shear layer and also the scattering of sound by the shear-layer turbulence. The transmission data essentially verify the proposed, theoretical calibration factor which forms part of a computational procedure that is being developed to convert model jet data from a free-jet facility to inflight conditions. (Author)

**A77-51083 \* #** Effect of simulated forward speed on the jet noise of inverted velocity profile conannular nozzles. A. B. Packman, K. W. Ng (United Technologies Corp., Pratt and Whitney Aircraft Group, East Hartford, Conn.), and C. Y. Chen (United Technologies Research Center, East Hartford, Conn.). *American Institute of Aeronautics and Astronautics, Aerodynamics Conference, 4th, Atlanta, Ga., Oct. 3-5, 1977, Paper 77-1329*. 12 p. 15 refs. Contract No. NAS3-17866.

Tests were conducted of inverted velocity profile conannular nozzles and a conical nozzle in an acoustic wind tunnel facility to simulate flight effects on jet noise generation. Conannular model nozzles were tested at fan to core nozzle exit area ratios of .75 and

1.2. Fan stream jet velocity ranged up to 2000 fps at a variety of fan exhaust pressure ratios and temperatures for a core stream of 1000 fps. The wind tunnel airflow was varied from static to 425 fps. The acoustic results indicated that the noise level differences seen previously under static conditions are retained in the flight environment. (Author)

## 72 ATOMIC AND MOLECULAR PHYSICS

Includes atomic structure and molecular spectra.

**A77-10534 \*** Production of Mg and Al Auger electrons by noble gas ion bombardment of Mg and Al surfaces. J. Ferrante and S. V. Pepper (NASA, Lewis Research Center, Cleveland, Ohio). *Surface Science*, vol. 58, no. 2, Aug. 1976, p. 613-617, 11 refs.

Relative production efficiencies of Mg and Al Auger electrons by He, Ne, Ar, Kr, and Xe ion bombardment are reported as a function of ion energy for energies not exceeding 3 keV. The experimental apparatus employed consisted of a LEED-Auger system equipped with an ion gun and a four-grid retarding-potential analyzer. It is found that: (1) the shape of the ion-excited Auger signal was independent of the rare gas and quite symmetric; (2) the Al signal was about an order of magnitude smaller than the Mg signal for a given bombarding species and ion-gun voltage; (3) no signal was observed for He(+) bombardment under any of the experimental conditions; (4) signal strengths were independent of temperature and ion dose; (5) the Auger production efficiencies differed by no more than a factor of two among the different gases - except for He(+) - on a given metal; (6) all the signal strengths increased with increasing ion-gun voltage, with no maximum exhibited; and (7) the apparent threshold energy for the Al signal was higher than that for the Mg signal. The differences between the results for the two metals are attributed to the fact that the Al 2p orbital lies deeper in energy and closer to the nucleus than the corresponding Mg orbital. F.G.M.

**A77-25149 \*** Generation of atomic H in a hydrogen matrix by tritium decay. F. J. Zeleznik (NASA, Lewis Research Center, Cleveland, Ohio). *Journal of Chemical Physics*, vol. 65, Dec. 1, 1976, p. 4492-4496.

Webeler's (1976) experimental results for the generation of atomic hydrogen in a hydrogen matrix by tritium decay are reexamined with a variant of Rosen's (1976) mathematical treatment. The analysis retains Rosen's equations for the number densities of trapped and mobile hydrogen atoms, but replaces his enthalpy equation with an equation for the directly measured temperature. Theoretical expressions are derived for the dependence of storage time, recombination time, and maximum density of trapped hydrogen atoms as a function of temperature for a given tritium concentration. A comparison of predictions for the maximum trapped atomic hydrogen number density as a function of storage time reveals that Rosen's estimate for the maximum number density of hydrogen atoms for the zero magnetic field case is a little more optimistic than the estimate obtained in the paper. S.D.

**A77-46588 \*** Properties of small Ar sub N-1 K/+ ionic clusters. R. D. Etters (NASA, Lewis Research Center, Cleveland, Ohio; Colorado State University, Fort Collins, Colo.), R. Danilowicz (Utica College, Utica, N.Y.), and J. Dugan (Science and Technology Committee, Washington, D.C.). *Journal of Chemical Physics*, vol. 67, Aug. 15, 1977, p. 1570-1575. 13 refs. Grant No. NGR-06-002-159.

A self-consistent formalism is developed that, based upon a many-body potential, dynamically determines the thermodynamic properties of ionic clusters without an a priori designation of the equilibrium structures. Aggregates consisting of a single closed shell K(+) ion and N-1 isoelectronic argon atoms were studied. The clusters form crystallites at low temperatures, and melting transitions and spontaneous dissociations are indicated. The results confirm experimental evidence that shows that ionic clusters become less stable with increasing N. The crystallite structures formed by four different clusters are isosceles triangle, skewed form, octahedron with ion in the middle, and icosahedron with the ion in the middle. M.L.

**N77-27880\*** IRT Corp., San Diego, Calif.  
**CROSS SECTIONS FOR CHARGE TRANSFER BETWEEN MERCURY IONS AND OTHER METALS** Final Report, Jun. 1973 - Apr. 1977

David A. Vroom and John A. Rutherford 16 Jun. 1977 54 p refs

(Contract NAS3-17759)

(NASA-CR-135205; Rept-8095-046)

Avail: NTIS

HC A04/MF A01 CSCI 20H

Cross sections for charge transfer between several ions and metals of interest to the NASA electro propulsion program have been measured. Specifically, the ions considered were Hg(+), Xe(+), and Cs(+), and the metals Mo, Fe, Al, Ti, Ta, and C. Measurements were made in the energy regime from 1 to 5,000 eV. In general, the cross sections for charge transfer were found to be less than 10 to the minus 15 power sq cm for most processes over the total energy range. Exceptions are Hg(+) in collision with Ti and Ta. The results obtained for each reaction are given in both graphical and numerical form in the text. For quick reference, the data at several ion velocities are condensed into one table given in the summary. Author



## 73 NUCLEAR AND HIGH-ENERGY PHYSICS

Includes elementary and nuclear particles; and reactor theory.

For space radiation see 93 *Space Radiation*.

**N77-12847\*** National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio.

### NONPULSIVE APPLICATIONS OF ION BEAMS

W. R. Hudson 1976 16 p refs Presented at the 12th Intern. Elec. Propulsion Conf., Key Biscayne, Fla., 15-17 Nov. 1976; sponsored by AIAA

(NASA-TM-X-73511; E-8851) Avail: NTIS HC A02/MF A01 CSCL 20J

Eight centimeter ion beam sources utilizing xenon and argon have been developed that operate over a wide range of beam energies and currents. Three types of processes have been studied: sputter deposition, ion beam machining, and ion beam surface texturing. The broad range of source operating conditions allows optimum sputter deposition of various materials. An ion beam source was used to ion mill laser reflection holograms using photorestat patterns on silicon. Ion beam texturing was tried with many materials and has a multitude of potential applications

Author

**N77-17840\*** National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio

### A PRELIMINARY AREA SURVEY OF NEUTRON RADIATION LEVELS ASSOCIATED WITH THE NASA VARIABLE ENERGY CYCLOTRON HORIZONTAL NEUTRON DELIVERY SYSTEM

W. K. Roberts and R. Leonard Dec. 1976 14 p ref

(NASA-TM-X-73577; E-9035) Avail: NTIS HC A02/MF A01 CSCL 21H

The 25 MeV deuteron beam from the NASA variable energy cyclotron incident on a thick beryllium target will deliver a tissue neutron dose rate of 2.14 rad/micron A-min at a source to skin distance of 125 cm. A neutron survey of the existing hallways with various shielding configurations made during operating of the horizontal neutron delivery system indicates that minimal amounts of additional neutron shielding material are required to provide a low level radiation environment within a self-contained neutron therapy control station. Measurements also indicate that the primary neutron distribution delivered by a planned vertical delivery system will be minimally perturbed by neutrons backscattered from the floor

Author

**A77-23322 \*** Evaluation of nuclear-reactor-produced iodine-123. J. W. Blue (NASA, Lewis Research Center, Cleveland, Ohio) and V. J. Sodd (Cincinnati General Hospital, Cincinnati, Ohio). *Medical Physics*, vol. 3, Sept.-Oct. 1976, p. 358, 359. 6 refs.

Iodine-123 has such great potential for nuclear medicine that all possible production methods should be considered. In this report, an experimental study related to I-123 production at a high-intensity fast-flux reactor using the reaction  $Xe-134(n,2n)Xe-123$  is considered. The conclusion is that I-123 could be made in small quantities and the cost would be higher than the cyclotron methods presently used.

(Author)

**N77-13820\*** Thermo Electron Corp., Waltham, Mass.

### HIGH EFFICIENCY THERMIONIC CONVERTER STUDIES

F. N. Huffman, A. H. Sommer, C. L. Balestra, D. P. Briere, and P. E. Oettinger Nov. 1976 127 p refs

(Contract NAS3-19866)

(NASA-CR-135125; TE4202-12-77) Avail: NTIS HC A07/MF A01 CSCL 10B

The objective is to improve thermionic converter performance by means of reduced interelectrode losses, greater emitter

capabilities, and lower collector work functions until the converter performance level is suitable for out-of-core space reactors and radioisotope generators. Electrode screening experiments have identified several promising collector materials. Back emission work function measurements of a ZnO collector in a thermionic diode have given values less than 1.3 eV. Diode tests were conducted over the range of temperatures of interest for space power applications. Enhanced mode converter experiments have included triodes operated in both the surface ionization and plasmatron modes. Pulsed triodes were studied as a function of pulse length, pulse potential, inert gas fill pressure, cesium pressure, spacing, emitter temperature and collector temperature. Current amplifications (i.e., mean output current/mean grid current) of several hundred were observed up to output current densities of one amp/sq cm. These data correspond to an equivalent arc drop less than 0.1 eV.

Author

## 74 OPTICS

Includes light phenomena.

**A77-26394 \* #** Optical properties of ion beam textured metals. W. R. Hudson, A. J. Weigand, and M. J. Firtich (NASA, Lewis Research Center, Cleveland, Ohio). *American Vacuum Society, Annual Symposium on Applied Vacuum Science and Technology, 6th, Tampa, Fla., Feb. 14-16, 1977, Paper. 19 p. 16 refs.*

Copper, silicon, aluminum, titanium and 316 stainless steel were textured by 1000 eV xenon ions from an 8-cm diameter electron bombardment ion source. Copper, silicon, and aluminum developed a cone structure with an average peak-to-peak distance ranging from 1 micron for silicon to 6 microns for aluminum. Titanium and 316 stainless steel developed a serpentine ridge structure. The average peak-to-peak distance for both of these materials was 0.5 micron. Total reflectance for air mass 0 and 2, solar absorptance, and total emittance, normalized for a 425 K black body were calculated from the reflectance measurements. All materials had solar absorptances between 0.93 (stainless steel) and 0.97 (silicon and aluminum). Total emittance values of 0.75, 0.80, and 0.85 for Si, Al, and Cu, respectively, resulted in a solar absorptance/total emittance ratio of approximately 1.2. Titanium and 316 stainless steel had values of 2.6 and 2.9, respectively, for this ratio. (Author)

**DATA SUMMARY:** Diverse data are presented; variables include ion-beam sputtering duration, peak-to-peak surface-structure spacing, surface-structure height, surface growth rate, total solar reflectance, solar infrared reflectance, solar absorptance for air mass zero, solar absorptance for air mass two, total emittance, collector stagnation temperature.

## 75 PLASMA PHYSICS

Includes magnetohydrodynamics and plasma fusion.  
For ionospheric plasmas see 46 Geophysics. For space plasmas see 90 Astrophysics.

**N77-17862\*** National Aeronautics and Space Administration  
Lewis Research Center, Cleveland, Ohio  
**ESTIMATE OF OPTIMAL GENERATING CONDITIONS FOR HYDROGEN-OXYGEN CESIUM-SEEDED MAGNETO-DYNAMIC POWER GENERATOR**  
J. Marlin Smith and Lester D. Nichols Washington Feb. 1977  
37 p refs  
(NASA-TN-D-8374; E-8828) Avail NTIS HC A03/MF A01  
CSCL 201

The value of percent seed, oxygen to fuel ratio, combustion pressure, Mach number, and magnetic field strength which maximize either the electrical conductivity or power density at the entrance of an MHD power generator was obtained. The working fluid is the combustion product of H<sub>2</sub> and O<sub>2</sub> seeded with CsOH. The ideal theoretical segmented Faraday generator along with an empirical form found from correlating the data of many experimenters working with generators of different sizes, electrode configurations, and working fluids, are investigated. The conductivity and power densities optimize at a seed fraction of 3.5 mole percent and an oxygen to hydrogen weight ratio of 7.5. The optimum values of combustion pressure and Mach number depend on the operating magnetic field strength. Author

**N77-19868\*** National Aeronautics and Space Administration  
Lewis Research Center, Cleveland, Ohio  
**A HEAVY ION BEAM PROBE SYSTEM FOR INVESTIGATION OF A MODIFIED PENNING DISCHARGE**  
George X. Kambic and Walter M. Krawczonek Mar 1977  
34 p refs  
(NASA-TM-X-3485; E-8869) Avail NTIS HC A03/MF A01  
CSCL 201

An ion beam probe diagnostic system can measure time- and space-resolved profiles of plasma space potential and electron density. In combination with a computer iterative technique, the ion beam probe can determine both the space potential profile in plasmas containing strong electric fields and potentials comparable in magnitude to the energy of the probing ion beam. During ion beam probing of a modified Penning discharge, several groups of secondary ions were observed coming from the plasma with a fixed primary beam energy and momentum. The energies of these ions were within 10 percent of the values predicted by a computer-generated model of the potential profile in the plasma. The mechanical and electronic components of the system are described, with particular emphasis on those features required to probe plasma potentials comparable in magnitude to the ion beam energy. Author

**N77-23936\*** National Aeronautics and Space Administration  
Lewis Research Center, Cleveland, Ohio  
**RESULTS OF CLOSED CYCLE MHD POWER GENERATION TEST WITH A HELIUM-CESIUM WORKING FLUID**  
Ronald J. Sovis 1977 10 p refs Presented at the 16th Symp on the Engr Aspects of Magnetohydrodynamics, Pittsburgh, Pa., 16-18 May 1977  
(NASA-TM-X-73621; E-9112) Avail NTIS HC A02/MF A01  
CSCL 201

The cross sectional dimensions of the MHD channel in the NASA Lewis closed loop facility were reduced to 3.8 x 11.4 cm. Tests were run in this channel using a helium-cesium working fluid at stagnation pressures of 160,000 n./M<sup>2</sup>, stagnation temperatures of 2000-2060 K and an entrance Mach number of 0.36. In these tests Faraday open circuit voltages of 200 V were measured which correspond to a Faraday field of 1750 V/M. Power generation tests were run for different groups of electrode configurations and channel lengths. Hall fields up to 1450 V/M were generated. Power extraction per electrode of 183 W and power densities of 1.7 MW/M<sup>2</sup> were obtained.

A total power output of 2 kW was generated for tests with 14 electrodes. The power densities obtained in this channel represent a factor of 3 improvement over those previously reported for the M O<sub>2</sub> channel. Author

**N77-23937\*** National Aeronautics and Space Administration  
Lewis Research Center, Cleveland, Ohio  
**SPECTROSCOPIC DETERMINATION OF ELECTRICAL CONDUCTIVITY IN AN MHD DUCT FROM ABSOLUTE INTENSITY MEASUREMENTS**  
S. Y. Wang and Marlin Smith 1977 1 p refs Presented at 16th Symp on Engr. Aspects of Magnetohydrodynamics, Pittsburgh, 16-18 May 1977  
(NASA-TM-X-73626; E-9118) Avail NTIS HC A02/MF A01  
CSCL 201

Measurements of the electrical conductivity in the NASA Lewis cesium seeded, H<sub>2</sub>-O<sub>2</sub> MHD duct have been previously reported. In order to corroborate the above measurements and to analyze the possibility of nonuniform seed injection as a cause of the deviations, a spectroscopic investigation of the plasma conductivity has been undertaken. Transverse profiles of the absolute integrated intensity were measured from the optically thin lines of CSI-5664 microns and 5636 microns. Radial profiles of emission coefficient were obtained from the measured transverse profiles of intensity by Abel inversion. Radial profiles of electrical conductivity were then obtained under two different assumptions. In the first, the Cs seed fraction is assumed uniform and equal to the measured flow rate at the time when the temperature and conductivity were obtained. In the second method, the local temperature and pressure are taken to be those given by a one-dimensional channel calculation including heat transfer and friction. In this case profiles of conductivity and seed fractions are obtained. The results of the two methods are compared to the previously measured conductivity. Author

**N77-24945\*** National Aeronautics and Space Administration  
Lewis Research Center, Cleveland, Ohio  
**NEUTRON MONITORING AND ELECTRODE CALORIMETRY EXPERIMENTS IN THE HIP-1 HOT ION PLASMA**  
John J. Reinmann and Robert W. Layman (Dartmouth Coll.) May 1977 27 p refs Presented at Am. Phys. Soc. Meeting, San Francisco, 15-19 Nov 1976  
(NASA-TM-X-3525; E-9063) Avail NTIS HC A03/MF A01  
CSCL 201

Results are presented for two diagnostic procedures on HIP-1, neutron diagnostics to determine where neutrons originated within the plasma discharge chamber and electrode calorimetry to measure the steady-state power absorbed by the two anodes and cathodes. Results are also reported for a hot-ion plasma formed with a continuous-cathode rod, one that spans the full length of the test section, in place of the two hollow cathodes. The outboard neutron source strength increased relative to that at the midplane when (1) the cathode tips were moved farther outboard, (2) the anode diameters were increased, and (3) one of the anodes was removed. The distribution of neutron sources within the plasma discharge chamber was insensitive to the division of current between the two cathodes. For the continuous cathode, increasing the discharge current increased the midplane neutron source strength relative to the outboard source strength. Each cathode absorbed from 12 to 15 percent of the input power regardless of the division of current between the cathodes. The anodes absorbed from 20 to 40 percent of the input power. The division of power absorption between the anodes varied with plasma operating conditions and electrode placement. Author

**N77-25983\*** National Aeronautics and Space Administration  
Lewis Research Center, Cleveland, Ohio  
**FACTORS AFFECTING ION KINETIC TEMPERATURE, NUMBER DENSITY, AND CONTAINMENT TIME IN THE NASA LEWIS BUMPY-TORUS PLASMA**  
J. Reece Roth Washington May 1977 67 p refs  
(NASA-TN-D-8466; E-9042) Avail NTIS HC A04/MF A01  
CSCL 201

The degree of toroidal symmetry of the plasma, the number of midplane electrode rings, the configuration of electrode rings, and the location of the diagnostic instruments with respect to the electrode rings used to generate the plasma are discussed. Impurities were deliberately introduced into the plasma, and the effects of the impurity fraction on ion kinetic temperature and electron number density were observed. It is concluded that, if necessary precautions are taken, the plasma communicates extremely well along the magnetic field lines and displays a high degree of symmetry from sector to sector for a wide range of electrode ring configurations and operating conditions. Finally, some characteristic data taken under nonoptimized conditions are presented, which include the highest electron number density and the longest particle containment time (1.9 msec) observed. Also, evidence from a paired comparison test is presented which shows that the electric field acting along the minor radius of the toroidal plasma improves the plasma density and the calculated containment time more than an order of magnitude if the electric field points inward, relative to the values observed when it points (and pushes ions) radially outward. Author

**N77-27915\*** National Aeronautics and Space Administration, Lewis Research Center, Cleveland, Ohio.

**OPTIMIZATION OF CONFINEMENT IN A TOROIDAL PLASMA SUBJECT TO STRONG RADIAL ELECTRIC FIELDS**

J. Reece Roth 1977 33 p refs Presented at Intern. Conf. on Plasma Sci., Troy, N. Y., 23-25 May 1977; sponsored by IEEE

(NASA-TM-X-73680; E-9225) Avail. NTIS HC A03/MF A01 CSCL 201

A preliminary report on the identification and optimization of independent variables which affect the ion density and confinement time in a bumpy torus plasma is presented. The independent variables include the polarity, position, and number of the midplane electrode rings, the method of gas injection, and the polarity and strength of a weak vertical magnetic field. Some characteristic data taken under condition when most of the independent variables were optimized are presented. The highest value of the electron number density on the plasma axis is  $3.2 \times 10^{10}$  to the 12th power/cc, the highest ion heating efficiency is 47 percent, and the longest particle containment time is 2.0 milliseconds. Author

**N77-27921\*** National Aeronautics and Space Administration, Lewis Research Center, Cleveland, Ohio.

**INVESTIGATION OF POSSIBLE LOWER HYBRID EMISSION FROM THE NASA LEWIS BUMPY TORUS PLASMA**

R. Mallavarpu and J. R. Roth May 1977 16 p refs Presented at the Intern. Conf. on Plasma Sci., Troy, N. Y., 23-25 May 1977; sponsored by IEEE

(NASA-TM-X-73689) Avail. NTIS HC A02/MF A01 CSCL 201

Radio frequency emission has been detected near the power hybrid frequency of a bumpy torus plasma by using a responsive detection system that consists of a spectrum analyzer and a 50 ohm miniature coaxial antenna concentrically located in a re-entrant quartz tube. The frequency shift of a broad emission peak was monitored as a function of background pressure, electrode voltage, and the strength of the dc magnetic field. Simultaneous measurements of the average plasma density were made with a polarization diplexing microwave interferometer. The information derived from the experiment is discussed with particular reference to the following: (1) whether the emissions are dominated by atomic or molecular species of deuterium; (2) the strength of the dc magnetic field in the emitting region; (3) the geometric location of the emitting region of the plasma; (4) comparison of the lower hybrid plasma density with the average plasma density; and (5) relation of ion spoke geometry to lower hybrid emission. Author

**N77-33996\*** National Aeronautics and Space Administration, Lewis Research Center, Cleveland, Ohio.

**A HOLLOW CATHODE HYDROGEN ION SOURCE**

J. S. Sovey and M. J. Mirtich Oct. 1977 10 p refs Presented at 7th Symp. on Eng. Probl. of Fusion Res., Knoxville, Tenn., 25-28 Oct. 1972; sponsored by IEEE Inc

(NASA-TM-73783; E-9345) Avail. NTIS HC A02/MF A01 CSCL 201

High current density ion sources have been used to heat plasmas in controlled thermonuclear reaction experiments. High beam currents imply relatively high emission currents from cathodes which have generally taken the form of tungsten filaments. A hydrogen ion source is described which was primarily developed to assess the emission current capability and design requirements for hollow cathodes for application in neutral injection devices. The hydrogen source produced ions by electron bombardment via a single hollow cathode. Source design followed mercury ion thruster technology, using a weak magnetic field to enhance ionization efficiency. Author

**N77-34000\*** National Aeronautics and Space Administration, Lewis Research Center, Cleveland, Ohio.

**ALTERNATIVE APPROACHES TO PLASMA CONFINEMENT**

J. Reece Roth May 1977 79 p refs Presented at Minicourse on Controlled Fusion, Troy, N. Y., 25-27 May 1977; sponsored by IEEE

(NASA-TM-X-73793; E-9361) Avail. NTIS HC A05/MF A01 CSCL 201

The potential applications of fusion reactors, the desirable properties of reactors intended for various applications, and the limitations of the Tokamak concept are discussed. The principles and characteristics of 20 distinct alternative confinement concepts are described, each of which may be an alternative to the Tokamak. The devices are classed as Tokamak-like, stellarator-like, mirror machines, bumpy ion, electrostatically assisted, magma concept, and wall-confined plasma. Author

**A77-39533 \*** Results of closed cycle MHD power generation tests with a helium-caesium working fluid. R. J. Sovie (NASA, Lewis Research Center, Cleveland, Ohio). In: Symposium on the Engineering Aspects of Magnetohydrodynamics, 16th, Pittsburgh, Pa., May 16-18, 1977, Proceedings. (A77-39526 18-75) Pittsburgh, Pa., Energy Research and Development Administration, 1977, p. II.1.1-II.1.6, 15 refs.

The cross-sectional dimensions of the MHD channel in the NASA Lewis closed loop facility have been reduced to 3.8 x 11.4 cm. Tests were run in this channel using a helium-caesium working fluid at stagnation pressures of  $1.6 \times 10$  to the 5th N/sq m, stagnation temperatures of 2000-2060 K and an entrance Mach number of 0.36. In these tests Faraday open circuit voltages of 200 V were measured which correspond to a Faraday field of 1750 V/m. Power generation tests were run for different groups of electrode configurations and channel lengths. Hall fields up to 1450 V/m were generated. Power extraction per electrode of 183 W and power densities of 1.7 MW/cu m have been obtained. A total power output of 2 kW was generated for tests with 14 electrodes. The power densities obtained in this channel represent a factor of 3 improvement over those reported for the m = 0.2 channel at the last EAM Symposium. (Author)

**A77-39546 \*** Spectroscopic determination of electrical conductivity in an MHD duct from absolute intensity measurements. S. Y. Wang and J. M. Smith (NASA, Lewis Research Center, Cleveland, Ohio). In: Symposium on the Engineering Aspects of Magnetohydrodynamics, 16th, Pittsburgh, Pa., May 16-18, 1977, Proceedings. (A77-39526 18-75) Pittsburgh, Pa., Energy Research and Development Administration, 1977, p. V.1.1 V.1.5, 11 refs.

Measurements of the electrical conductivity in the NASA Lewis caesium seeded, H2-O2 MHD duct made by applying a voltage across the channel from one end electrode to the other, measuring the

current, and using the inner electrodes as probes to monitor the voltage distribution along the channel were found to be in good agreement with theory except at low combustion pressures and/or high ratios of seed/oxygen mass flows. To corroborate these measurements and to analyze the possibility of nonuniform seed injection as a cause of the above deviations, a spectroscopic investigation of the plasma conductivity was undertaken. Radial profiles of emission coefficient were obtained from measured transverse profiles of the absolute integrated intensity by Abel inversion. Radial profiles of electrical conductivity were then obtained under two different assumptions. In the first the Cs seed fraction is assumed uniform and equal to the measured flow rate at the time when the temperature and conductivity were obtained. In the second method the local temperature and pressure are taken to be those given by a one-dimensional channel calculation including heat transfer and friction. The results of the two methods are compared to the previously measured conductivity. (Author)

**A77-47958\* #** Optimization of confinement in a toroidal plasma subject to strong radial electric fields. J. R. Roth (NASA, Lewis Research Center, Cleveland, Ohio), *Institute of Electrical and Electronics Engineers, International Conference on Plasma Science, Troy, N.Y., May 23-25, 1977, Paper*. 32 p, 20 refs.

The toroidal ring of plasma contained in the NASA Lewis Bumpy Torus facility may be biased to positive or negative potentials approaching 50 kV by applying dc voltages of the respective polarity to 12 or fewer midplane electrode rings. The radial electric fields, which are responsible for raising the ions to high energies by  $E \times B/B^2$ -squared drift, then point out of or into the plasma. A preliminary report is given on the identification and optimization of independent variables which affect the ion density and confinement time in the Bumpy Torus plasma. The independent variables include the polarity, position, and number of the midplane electrode rings, the method of gas injection, and the polarity and strength of a weak vertical magnetic field. Some characteristic data taken under conditions where most of the independent variables were optimized are presented. The highest value of the electron number density on the plasma axis is 3.2 trillion per cu cm, the highest ion heating efficiency is 47%, and the longest particle containment time is 2.0 msec. (Author)

**A77-47959\* #** Investigation of possible lower hybrid emission from the NASA Lewis Bumpy Torus plasma. R. Mallavarpu and J. R. Roth (NASA, Lewis Research Center, Cleveland, Ohio), *Institute of Electrical and Electronics Engineers, International Conference on Plasma Science, Troy, N.Y., May 23-25, 1977, Paper*. 15 p, 7 refs.

Radio frequency emission detected near the lower hybrid frequency of the NASA Lewis Bumpy Torus plasma is studied, using a simple detection system that consists of a spectrum analyzer and a 50-ohm miniature co-axial antenna concentrically located in a re-entrant quartz tube. The frequency shift of a broad emission peak is monitored as a function of the background pressure, electrode voltage, and the strength of the dc magnetic field. Simultaneous measurements of the average plasma density are made with a polarization diplexing microwave interferometer. Information from the experiment is discussed with particular reference to the role of atomic or molecular species of deuterium in the emissions, the strength of the dc magnetic field in the emitting region, the geometric location of the emitting region of the plasma, the lower hybrid plasma density as compared with the average plasma density, and the relation of the ion spoke geometry to the lower hybrid emission. (Author)

**N77-13842\* #** Colorado State Univ., Fort Collins. Dept. of Physics.

**INTERACTION OF A SOLAR ARRAY WITH AN ION THRUSTER DUE TO THE CHARGE-EXCHANGE PLASMA**  
Annual Report

Harold R. Kaufman Oct. 1976 62 p refs

(Grant NsG-3038)

(NASA-CR-135099) Avail: NTIS HC A04/MF A01 CSCL 201

The generation of a charge exchange plasma by a thruster, the transport of this plasma to the solar array, and the interaction of the solar array with the plasma after it arrives are all described. The generation of this plasma is described accurately from thruster geometry and operating conditions. The transport of the charge exchange plasma was studied experimentally with a 15 cm thruster. A model was developed for simple thruster array configurations. A variety of experiments were surveyed for the interaction of the plasma at the solar array. Author

**N77-20886\* #** Magnetic Corp. of America, Waltham, Mass. Technical Report, Sep. 1975 - Dec. 1976  
**DESIGN STUDY OF SUPERCONDUCTING MAGNETS FOR A COMBUSTION MAGNETOHYDRODYNAMIC (MHD) GENERATOR**

Richard J. Thome and John W. Ayers Mar. 1977 255 p refs (Contract NAS3-19885)

(NASA-CR-135178) Avail: NTIS HC A12/MF A01 CSCL 201  
Design trade off studies for 13 different superconducting magnet systems were carried out. Based on these results, preliminary design characteristics were prepared for several superconducting magnet systems suitable for use with a combustion driven MHD generator. Each magnet generates a field level of 8 T in a volume 1.524 m (60 in.) long with a cross section 0.254 m x 0.254 m (10 in. x 10 in.) at the inlet and 0.406 m x .406 m (16 in. x 16 in.) at the outlet. The first design involves a racetrack coil geometry intended for operation at 4.2 K; the second design uses a racetrack geometry at 2.0 K, and the third design utilizes a rectangular saddle geometry at 4.2 K. Each case was oriented differently in terms of MHD channel axis and main field direction relative to gravity in order to evaluate fabrication ease. All cases were designed such that the system could be disassembled to allow for alteration of field gradient in the MHD channel by changing the angle between coils. Preliminary design characteristics and assembly drawings were generated for each case. Author

**A77-12786\* #** System studies of coal fired-closed cycle MHD for central station power plants. B. Zauderer (GE Space Sciences Laboratory, Philadelphia, Pa.). In: *Intersociety Energy Conversion Engineering Conference*, 11th, State Line, Nev., September 12-17, 1976, Proceedings, Volume 2. (A77 12652 02-44) New York, American Institute of Chemical Engineers, 1976, p. 1033-1039. 20 refs. Contract No. NAS3-19406.

This paper presents a discussion of the closed cycle MHD results obtained in a recent study of various advanced energy-conversion power systems. The direct coal-fired MHD topping-steam bottoming cycle was established as the current choice for central station power generation. Emphasis is placed on the background assumptions and the conclusions that can be drawn from the closed-cycle MHD analysis. It is concluded that closed-cycle MHD has efficiencies comparable to that of open-cycle MHD. Its cost will possibly be slightly higher than that of the open-cycle MHD system. Also, with reasonable fuel escalation assumptions, both systems can produce lower-cost electricity than conventional steam power plants. Suggestions for further work in closed-cycle MHD components and systems are made. (Author)

**A77-21267\* #** System studies of coal fired-closed cycle MHD for central station power plants. B. Zauderer (GE Space Sciences Laboratory, Philadelphia, Pa.). In: *Engineering aspects of magnetohydrodynamics; Proceedings of the Fifteenth Symposium*, Philadelphia, Pa., May 24-26, 1976. (A77-21214 08-75) Philadelphia, Pa., GE Space Sciences Laboratory, 1976, p. III.5.1-III.5.15. 20 refs. ERDA-NSF-supported research; Contract No. NAS3-19406.

This paper presents a discussion of the closed cycle MHD results obtained in a recent study of various advanced energy conversion (ECAS) power systems. The study was part of the first phase of this ECAS study. Since this was the first opportunity to evaluate the coal fired closed cycle MHD system, a number of iterations were required

to partially optimize the system. The present paper deals with the latter part of the study in which the direct coal fired, MHD topping-steam bottoming cycle was established as the current choice for central station power generation. The emphasis of the paper is on the background assumptions and the conclusions that can be drawn from the closed cycle MHD analysis. The author concludes that closed cycle MHD has efficiencies comparable to that of open cycle MHD and that both systems are considerably more efficient than the other system studies in Phase 1 of the GE ECAS. Its cost will possibly be slightly higher than that of the open cycle MHD system. Also, with reasonable fuel escalation assumptions, both systems can produce lower cost electricity than conventional steam power plants. Suggestions for further work in closed cycle MHD components and systems is made. (Author)

**A77-36381 \***      **Design of closed-cycle MHD generator with nonequilibrium ionization and system.** R. E. Voshall, R. J. Wright, and R. W. Liebermann (Westinghouse Research Laboratories, Pittsburgh, Pa.). *IEEE Transactions on Plasma Science*, vol. PS-5, June 1977, p. 110-112. 16 refs. Contract No. NAS3-19407.

A method is developed to include the nonequilibrium ionization process in the MHD generator duct design equations, and these equations are coupled to the thermodynamic conditions of the closed cycle system. This is used to relate MHD generator size, configuration and gas conditions to the overall thermodynamic efficiency of the system. The system studied consists of an MHD loop (Ar + Cs or He + Cs) topping a steam bottoming plant. B.J.

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Includes superconductivity.  
For related information, see also 33 Electronics and Electrical Engineering and 36 Lasers and Masers.

**N77-19901\*** National Aeronautics and Space Administration, Lewis Research Center, Cleveland, Ohio.  
**THE USE OF ANALYTICAL SURFACE TOOLS IN THE FUNDAMENTAL STUDY OF WEAR**  
Donald H. Buckley 1977 84 p refs Proposed for presentation at Intern. Conf. on Wear of Mater., St. Louis, 25-27 Apr. 1977; sponsored by ASME  
(NASA-TM-X-73437; E-8792) Avail: NTIS HC A04/MF A01 CSCL 20L

Various techniques and surface tools available for the study of the atomic nature of the wear of materials are reviewed. These include chemical etching, x-ray diffraction, electron diffraction, scanning electron microscopy, low-energy electron diffraction, Auger emission spectroscopy analysis, electron spectroscopy for chemical analysis, field ion microscopy, and the atom probe. Properties of the surface and wear surface regions which affect wear, such as surface energy, crystal structure, crystallographic orientation, mode of dislocation behavior, and cohesive binding, are discussed. A number of mechanisms involved in the generation of wear particles are identified with the aid of the aforementioned tools.

Author

**N77-32841\*** National Aeronautics and Space Administration, Lewis Research Center, Cleveland, Ohio.  
**FRICITION, DEFORMATION AND FRACTURE OF SINGLE-CRYSTAL SILICON CARBIDE**  
Kazuhiya Miyoshi (Kanazawa Univ., Japan) and Donald H. Buckley Oct. 1977 40 p refs Presented at Joint Lubrication Conf., Kansas City, Mo., 3-5 Oct. 1977; sponsored by Am. Soc. of Lubrication Engineers and ASME  
(NASA-TM-73705; E-9121-1) Avail: NTIS HC A03/MF A01 CSCL 20B

Friction experiments were conducted with hemispherical and conical diamond riders sliding on the basal plane of silicon carbide. The results indicate that, when deformation is primarily elastic, the friction does not depend on crystallographic orientation and there is no detectable fracture or cracking. When, however, plastic deformation occurs, silicon carbide exhibits anisotropic friction and deformation behavior. Surface fracture crack patterns surrounding wear tracks are observed to be of three types. The crack-geometries of two types are generally independent of orientation; the third crack, however, depends on the orientation. All surface cracks extend into subsurface. Anisotropic friction, deformation and fracture on the basal plane are primarily controlled by the slip system and cleavage.

Author

**A77-10993\*** Superconducting critical fields of alkali and alkaline-earth intercalates of MoS<sub>2</sub>. J. A. Woollam (NASA, Lewis Research Center, Cleveland, Ohio) and R. B. Somoano (California Institute of Technology, Jet Propulsion Laboratory, Pasadena, Calif.). *Physical Review B - Solid State*, 3rd Series, vol. 13, May 1, 1976, p. 3843-3853. 33 refs. Contract No. NAS7-100.

Results are reported for measurements of the critical-field anisotropy and temperature dependence of group-VIB semiconductor MoS<sub>2</sub> intercalated with the alkali and alkaline-earth metals Na, K, Rb, Cs, and Sr. The temperature dependences are compared with present theories on the relation between critical field and transition temperature in the clean and dirty limits over the reduced-temperature range from 1 to 0.1. The critical-field anisotropy data are compared with predictions based on coupled-layers and thin-film ('independent-layers') models. It is found that the critical-field boundaries are steep in all cases, that the fields are greater than theoretical predictions at low temperatures, and that an unusual positive curvature in the temperature dependence appears which may be related to the high anisotropy of the layer structure. The results show that materials with the largest ionic intercalate atom diameters

and hexagonal structures (K, Rb, and Cs compounds) have the highest critical temperatures, critical fields, and critical-boundary slopes; the critical fields of these materials are observed to exceed the paramagnetic limiting fields.

F.G.M.

**A77-16982\*** Electron microscopic and optical studies of prism faces of synthetic quartz. B. C. Buzek (NASA, Lewis Research Center, Cleveland, Ohio) and A. S. Vagh (Ball State University, Muncie, Ind.). *Journal of Materials Science*, vol. 12, Jan. 1977, p. 153-156. 5 refs.

Application of electron and optical microscopic techniques to the study of growth spirals on quartz crystal faces is described. Attention is centered on the centers of the spirals and on screw ledges; overhanging kinks are revealed on one side of the spiral centers. The possibility that these special features may have developed after growth of the crystals went to completion is explored. The conjecture is raised that such structures might result from adsorption of growth-inhibiting impurities at the center of the growth spiral on the quartz habit faces.

R.D.V.

**A77-17587\*** Metal interfaces - Adhesive energies and electronic barriers. J. Ferrante (NASA, Lewis Research Center, Cleveland, Ohio) and J. R. Smith (GM Research Laboratories, Warren, Mich.). *Solid-State Communications*, vol. 20, no. 4, 1976, p. 393-396. 14 refs.

We report a fully self-consistent calculation of the electron number density, barrier height and adhesive energy as a function of separation in an aluminum-aluminum (100) contact. The local density approximation is used for exchange and correlation. The electron number density and barrier heights are strong functions of the separation. The range of strong chemical bonding is about 0.2 nm.

(Author)

**A77-32240\*** Superconductivity in sputtered CuMoSS<sub>8</sub>. S. Alterovitz, J. A. Woollam (NASA, Lewis Research Center, Cleveland, Ohio), L. Kammerdiner, H.-L. Luo (NASA, Lewis Research Center, Cleveland, Ohio; California, University, San Diego, Calif.), and C. Martin. *American Physical Society, General Meeting, San Diego, Calif., Mar. 20-24, 1977, Paper*. 13 p. 18 refs.

The superconducting transition temperature and the superconducting upper critical fields for sputtered films of copper-containing ternary molybdenum chalcogenides (chevrel phases) were determined. The theory presented by Werthamer, Helfand, and Hohenberg (WHH) (1966) was used to make computer-generated plots of the superconducting upper critical field values versus the superconducting transition temperature values for various values of the Maki paramagnetic pair-breaking parameter and the spin-orbit scattering parameter. The interpretation of the graph suggests that the experimental data for at least one sample are above the maximum WHH theoretical limit in the lower temperature range. Possible explanations of this situation are discussed. In other calculations, a scaling law was found suitable for determining pinning force densities; this data was used to calculate critical current values. The relation between resistivity and temperature was studied.

M.L.

**A77-37043\*** Magnetic Stirling cycles - A new application for magnetic materials. G. V. Brown (NASA, Lewis Research Center, Cleveland, Ohio). *Institute of Electrical and Electronics Engineers, International Magnetism Conference, Los Angeles, Calif., June 6-10, 1977, Paper*. 5 p.

There is the prospect of a fundamental new application for magnetic materials as the working substance in thermodynamic cycles. Recuperative cycles which use a rare-earth ferromagnetic material near its Curie point in the field of a superconducting magnet appear feasible for applications from below 20 K to above room temperature. The elements of the cycle, advanced in an earlier paper, are summarized. The basic advantages include high entropy density

in the magnetic material, completely reversible processes, convenient

control of the entropy by the applied field, the feature that heat transfer is possible during all processes, and the ability of the ideal cycle to attain Carnot efficiency. The mean field theory is used to predict the entropy of a ferromagnet in an applied field and also the isothermal entropy change and isentropic temperature change caused by applying a field. Results are presented for  $J = 7/2$  and  $g = 2$ . The results for isentropic temperature change are compared with experimental data on Gd. Coarsely mixtures of ferromagnetic materials with different Curie points are proposed to modify the path of the cycle in the T-S diagram in order to improve the efficiency or to increase the specific power.

(Author)

**A77-39342 \*** Magnetization and magnetic susceptibility of **GdH<sub>3</sub>**. D. J. Flood (NASA, Lewis Research Center, Cleveland, Ohio). *Physics Letters*, vol. 60A, Mar. 21, 1977, p. 463, 464. 7 refs.

**A77-40158 \*** Electron microscopy of ferroelectric bismuth oxides containing perovskite layers. J. L. Hutchison, J. S. Anderson (Oxford University, Oxford, England), and C. N. R. Rao (Oxford University, Oxford, England; Indian Institute of Science, Bangalore, India). *Royal Society (London), Proceedings, Series A*, vol. 355, no. 1682, July 13, 1977, p. 301-312. 15 refs. Research supported by the Science Research Council.

Ferroelectric bismuth oxides of the general formula  $(\text{Bi}_2\text{O}_2)^{2+}/(\text{An}-1\text{BnO}_3\text{n}+1)^{2-}/2-$  (A = Ba, etc.; B = Ti or other transition metal) have been examined by high-resolution lattice-imaging electron microscopy. The lattice images show dark bands at the positions of the  $\text{Bi}_2\text{O}_2$  layers, with n-1 lines between them due to the layers of the perovskite A cations or, in favorable circumstances, the fully resolved 0.4-nm-square perovskite grid. Dislocations and domain boundaries have been imaged in ferroelectric crystals. The structure of the dislocations and domain walls is discussed in the light of the microstructural evidence.

(Author)

**A77-50694 \*** Critical currents in sputtered copper molybdenum sulphide. S. A. Alterovitz, J. A. Woolham (NASA, Lewis Research Center, Cleveland, Ohio), L. Kammerdiner, and H.-L. Luo (California, University, La Jolla, Calif.). *Applied Physics Letters*, vol. 31, Aug. 1, 1977, p. 233, 234. 11 refs.

Critical currents in a sputtered Chevrel phase copper molybdenum sulfide have been measured at 4.2 K as a function of applied magnetic field. Self-field critical-current values up to 10 to the 9th A/sq m were found, decreasing to 10 to the 8th A/sq m at 3 T. Graphs of pinning forces versus field were found to be independent of field direction, and the pinning mechanism is sample independent. Critical-current densities for sputtered lead molybdenum sulphide are estimated to be about 10 to the 8th A/sq m at 26 T based on a scaling law for pinning.

(Author)

**A77-45301 \*** Low-work-function surfaces produced by cesium carbonate decomposition. T. R. Briere and A. H. Sommer (Thermo Electron Corp., Waltham, Mass.). *Journal of Applied Physics*, vol. 48, Aug. 1977, p. 3547-3550. 16 refs. Contract No. NAS3-20302.

Cesium carbonate ( $\text{Cs}_2\text{CO}_3$ ) was heated to the decomposition temperature of approximately 600 C. The nonvolatile decomposition products were condensed on a nickel substrate while the carbon dioxide was removed by pumping. The deposited material is characterized by an effective work function of between 1.05 and 1.15 eV at 450 K and by photoemission in the visible and near-infrared region of the spectrum. It is suggested that the deposited material consists of  $\text{Cs}_2\text{O}$ , possibly  $\text{Cs}_2\text{O}_2$ , and adsorbed cesium. Silver, evaporated from a heated silver bead, produced the typical photoemissive and thermionic properties of a silver-oxygen-cesium (S-1) photocathode. The material may be of interest for thermionic energy converters and for the formation of silver oxygen-cesium photocathodes.

(Author)



## 77 THERMODYNAMICS AND STATISTICAL PHYSICS

Includes quantum mechanics; and Bose and Fermi statistics.

For related information see also 25 *Inorganic and Physical Chemistry* and 34 *Fluid Mechanics and Heat Transfer*.

**N77-10933\*** National Aeronautics and Space Administration Lewis Research Center, Cleveland, Ohio.

### REVISED INTERNATIONAL REPRESENTATIONS FOR THE VISCOSITY OF WATER AND STEAM AND NEW REPRESENTATIONS FOR THE SURFACE TENSION OF WATER

R. C. Hendricks, R. B. McClintock (GE Co., Schenectady, N. Y.), and G. J. Silvestri (Westinghouse Elec. Corp., Philadelphia, Pa.) 1976 53 p refs. Proposed for presentation at Winter Ann. Meeting of the Am. Soc. of Mech. Engr., New York, 5-10 Dec. 1976. Revised (NASA-TM-X-73483, E-8706) Avail. NTIS HC A04/MF A01 CSCL 20M

A skeleton table and formulation for viscosity is presented. The formulation is valid from the triple point to 1100 K (2000 R) and pressures to 100 MPa (15,000 psia). Comparisons are made between the calculated and the skeletal table values, and also between the new values and those in the 1967 ASME Steam Tables. A set of figures and tables in both English and SI units are presented to replace those in the steam tables. Sources for computer programs are given. Author

**N77-17919\*** National Aeronautics and Space Administration Lewis Research Center, Cleveland, Ohio.

### MODELING THE COMPLETE OTTO CYCLE: PRELIMINARY VERSION

Frank J. Zeleznik and Bonnie J. McBride 1977 46 p refs. Presented at the Automotive Engineering Congr. and Exposition, Detroit, 28 Feb. - 4 Mar. 1977, sponsored by the Soc. of Automotive Engineers (NASA-TM-X-73593, E-9065) Avail. NTIS HC A03/MF A01 CSCL 20M

A description is given of the equations and the computer program being developed to model the complete Otto cycle. The program incorporates such important features as: (1) heat transfer, (2) finite combustion rates, (3) complete chemical kinetics in the burned gas, (4) exhaust gas recirculation, and (5) manifold vacuum or supercharging. Changes in thermodynamic, kinetic and transport data as well as model parameters can be made without reprogramming. Preliminary calculations indicate that: (1) chemistry and heat transfer significantly affect composition and performance, (2) there seems to be a strong interaction among model parameters, and (3) a number of cycles must be calculated in order to obtain steady-state conditions. Author

**N77-28015\*** National Aeronautics and Space Administration Lewis Research Center, Cleveland, Ohio.

### GASLOT - A COMPUTER GRAPHICS PROGRAM THAT DRAWS A VARIETY OF THERMOPHYSICAL PROPERTY CHARTS

Roger J. Trivisonno and Robert C. Hendricks Washington, D. C. Jun 1977 58 p refs (NASA-TN-D-8507, E-8627) Avail. NTIS HC A04/MF A01 CSCL 20M

A FORTRAN V computer program, written for the UNIVAC 1100 series, is used to draw a variety of precision thermophysical property charts on the Calcomp plotter. In addition to the program (GASLOT), which requires (15 160) sub 10 storages, a thermophysical properties routine needed to produce plots. The program is designed so that any two of the state variables, the derived variables, or the transport variables may be plotted as the ordinate - abscissa pair with as many as five parametric variables. The parameters may be temperature, pressure, density,

enthalpy, and entropy. Each parameter may have as many as 49 values, and the range of the variables is limited only by the thermophysical properties routine. Author

**N77-30995\*** National Aeronautics and Space Administration Lewis Research Center, Cleveland, Ohio.

### SIMULATION OF THE HEAT TRANSFER CHARACTERISTICS OF LOX

R. C. Hendricks 17 Aug. 1977 10 p refs. Presented at the 17th Natl. Heat Transfer Conf., Salt Lake City, 14-17 Aug. 1977, sponsored by the Am. Soc. of Mech. Engr (NASA-TM-X-73634) Avail. NTIS HC A02/MF A01 CSCL 20M

Forced convection heat transfer data for fluid nitrogen flowing through a vertical tube were acquired and assumed to simulate the heat transfer characteristics of LOX. Comparisons between LN2 and LOX data over the pressure range for T sub r < 1 using a modified form of Petukhov's correlation factor was shown, qualitatively, to substantiate the simulation. Other parameters (buoyancy, Stanton number, and relative velocity), were found to group those data, assessment of these parametric interrelations must be made before the simulation can be termed quantitative. Author

**N77-30999\*** National Aeronautics and Space Administration Lewis Research Center, Cleveland, Ohio.

### VELOCITY AND TEMPERATURE PROFILES IN NEAR-CRITICAL NITROGEN FLOWING PAST A HORIZONTAL FLAT PLATE

Robert J. Simoneau 17 Aug. 1977 12 p refs. Presented at 17th Natl. Heat Transfer Conf., Salt Lake City, 14-17 Aug. 1977, sponsored by the Am. Soc. of Mechanical Engineers (NASA-TM-X-73635) Avail. NTIS HC A02/MF A01 CSCL 20M

Boundary layer velocity and temperature profiles were measured for nitrogen near its thermodynamic critical point flowing past a horizontal flat plate. The results were compared measurements made for vertically upward flow. The boundary layer temperatures ranged from below to above the thermodynamic critical temperature. For wall temperatures below the thermodynamic critical temperature there was little variation between the velocity and temperature profiles in three orientations. In all three orientations the point of crossing into the critical temperature region is marked by a significant flattening of the velocity and temperature profiles and also a decrease in heat transfer coefficient. Author

**A77-44562\*** Modeling the complete Otto cycle - Preliminary version. F. J. Zeleznik and B. J. McBride (NASA, Lewis Research Center, Cleveland, Ohio). *Society of Automotive Engineers, International Automotive Engineering Congress and Exposition, Detroit, Mich., Feb. 28-Mar. 4, 1977, Paper 770223*, 19 p, 19 refs.

A description is given of the equations and the computer program being developed to model the complete Otto cycle. The program incorporates such important features as: (1) heat transfer, (2) finite combustion rates, (3) complete chemical kinetics in the burned gas, (4) exhaust gas recirculation, and (5) manifold vacuum or supercharging. Changes in thermodynamic, kinetic and transport data as well as model parameters can be made without reprogramming. Preliminary calculations indicate that: (1) chemistry and heat transfer significantly affect composition and performance, (2) there seems to be a strong interaction among model parameters, and (3) a number of cycles must be calculated in order to obtain steady-state conditions. (Author)

## 82 DOCUMENTATION AND INFORMATION SCIENCE

Includes information storage and retrieval technology; micrography; and library science.

For computer documentation see 61 *Computer Programming and Software*.

**N77-11901\*** National Aeronautics and Space Administration  
Lewis Research Center, Cleveland, Ohio.

### **VOCABULARY OF AEROSPACE SAFETY TERMS PERTAIN- ING TO CRYOGENIC SAFETY, FIRES, EXPLOSIONS, AND STRUCTURE FAILURE**

James J. Pelouch, Jr., George Mandel, and Paul M. Ordin Sep.  
1976 122 p

(NASA-TM-X-73521; E-8935) Avail NTIS HC A06/MF A01  
CSCL 05B

This vocabulary listing characterizes the contents of over 10,000 documents of the NASA Aerospace Safety Research and Data Institute's (ASRDI) safety engineering collection. The ASRDI collection is now one of the series accessible on the NASA RECON data base. There are approximately 6,300 postable terms that describe literature in the areas of cryogenic fluid safety, specifically hydrogen, oxygen, liquified natural gas; fire and explosion technology; and the mechanics of structural failure. To facilitate the proper selection of information nonpostable, related and array terms have been included in this listing. Author

## 83 ECONOMICS AND COST ANALYSIS

Includes cost effectiveness studies.

**N77-11908\*** National Aeronautics and Space Administration  
Lewis Research Center, Cleveland, Ohio

### **COST-BENEFIT ANALYSIS OF SPACE TECHNOLOGY**

Gerald F. Hein, Steven M. Stevenson, and Joseph N. Sivo  
Washington, Nov 1976 26 p refs  
(NASA-TM-X-3453, E-8796) Avail NTIS HC A03/MF A01  
CSCL 05C

A discussion of the implications and problems associated with the use of cost-benefit techniques is presented. Knowledge of these problems is useful in the structure of a decision making process. A methodology of cost-benefit analysis is presented for the evaluation of space technology. The use of the methodology is demonstrated with an evaluation of ion thrusters for north-south stationkeeping aboard geosynchronous communication satellites. A critique of the concept of consumers surplus for measuring benefits is also presented.

Author

## 85 URBAN TECHNOLOGY AND TRANSPORTATION

Includes applications of space technology to urban problems: technology transfer; technology assessment; and surface and mass transportation.

For related information see 03 Air Transportation and Safety, 16 Space Transportation, and 44 Energy Production and Conversion.

**N77-17847\*** National Aeronautics and Space Administration, Lewis Research Center, Cleveland, Ohio.

### RESULTS OF BASELINE TESTS OF THE LUCAS LIMOUSINE

Richard F. Soltis, Miles O. Dustin, and Noel B. Sargent Jan. 1977 29 p. Sponsored in part by ERDA (NASA-TM-X-73609; E-9075) Avail: NTIS HC A03/MF A01 CSCL 13F

The Lucas Limousine, an electric vehicle, was tested to assess the state-of-the-art of electric vehicles. All tests were made without the regenerative braking system and were conducted at the gross vehicle weight of 7,700 pounds. Over a 30 mph stop and go driving cycle the vehicle went 48.4 miles. The vehicle was able to accelerate to 30 mph in about 15 seconds with a gradeability limit of 16.5 percent. As determined by coast down tests the road power and road energy consumption for the vehicle were 2.92 kilowatts and 0.146 kWh/mi, respectively, at 20 mph. At 40 mph, the road power requirement was 11.12 kilowatts and the road energy requirement was 0.278 kWh/mi. The maximum energy economy measured 0.45 kilowatt hours per mile at 30 mph and increased to 0.76 kilowatt hours per mile at 50 mph. Over the 30 mph stop and go driving cycle the energy economy was 0.92 kilowatt hours per mile.

Author

**N77-27035\*** National Aeronautics and Space Administration, Lewis Research Center, Cleveland, Ohio.

### A COMPUTERIZED TRAFFIC CONTROL ALGORITHM TO DETERMINE OPTIMAL TRAFFIC SIGNAL SETTINGS Ph.D. Thesis - Toledo Univ.

Kurt Seldner Mar. 1977 255 p refs (NASA-TM-X-73607; E-9084) Avail: NTIS HC A12/MF A01 CSCL 13F

An algorithm was developed to optimally control the traffic signals at each intersection using a discrete time traffic model applicable to heavy or peak traffic. Off line optimization procedures were applied to compute the cycle splits required to minimize the lengths of the vehicle queues and delay at each intersection. The method was applied to an extensive traffic network in Toledo, Ohio. Results obtained with the derived optimal settings are compared with the control settings presently in use.

Author

**A77-22879\*** The computer simulation of automobile use patterns for defining battery requirements for electric cars. H. J. Schwartz (NASA, Lewis Research Center, Cleveland, Ohio). *Union Internationale des Producteurs et Distributeurs d'Energie Electrique and Electric Vehicle Council, International Electric Vehicle Symposium, 4th, Dusseldorf, West Germany, Aug. 31-Sept. 2, 1976, Paper, 15 p.* 10 refs.

The modeling process of a complex system, based on the calculation and optimization of the system parameters, is complicated in that some parameters can be expressed only as probability distributions. In the present paper, a Monte Carlo technique was used to determine the daily range requirements of an electric road vehicle in the United States from probability distributions of trip lengths, frequencies, and average annual mileage data. The analysis shows that a daily range of 82 miles meets to 95% of the car-owner requirements at all times with the exception of long vacation trips. Further, it is shown that the requirement of a daily range of 82 miles can be met by a (intermediate-level) battery technology characterized by an energy density of 30 to 50 Watt-hours per pound. Candidate batteries in this class are nickel-zinc, nickel-iron, and iron-air. These

results imply that long-term research goals for battery systems should be focused on lower cost and longer service life, rather than on higher energy densities.

V.P.

**A77-35308\*** Establishing effective working relations with a potential user community - NASA Lewis Research Center experience. P. Foster (NASA, Lewis Research Center, Cleveland, Ohio). In: Space Congress, 14th, Cocoa Beach, Fla., April 27-29, 1977, Proceedings. (A77-35301 15-12) Cocoa Beach, Fla., Canaveral Council of Technical Societies, 1977, p. 2-6 to 2-11.

The NASA Lewis Research Center has held a series of six major and unique technology utilization conferences which were major milestones in planned structured efforts to establish effective working relationships with specific technology user communities. These efforts were unique in that the activities undertaken prior to the conference were extensive, and effectively laid the groundwork for productive technology transfer following, and as a direct result of, the conferences. The effort leading to the conference was in each case tailored to the characteristics of the potential user community, however, the common factors comprise a basic framework applicable

to similar endeavors. The process is essentially a planned sequence of steps that constitute a technical market survey and a marketing program for the development of beneficial applications of aerospace technology beyond the aerospace field.

(Author)

### N77-32033\* Detroit Diesel Allison, Indianapolis, Ind. STUDY AND PROGRAM PLAN FOR IMPROVED HEAVY DUTY GAS TURBINE ENGINE CERAMIC COMPONENT DEVELOPMENT Final Report

H. E. Helms May 1977 161 p refs Sponsored by ERDA (Contract NAS3-20064) (NASA-CR-135230; EDR-9068; ERDA/NASA/3-20064/77/1; Avail: NTIS HC A08/MF A01 CSCL 13F

Fuel economy in a commercially viable gas turbine engine was demonstrated through use of ceramic materials. Study results show that increased turbine inlet and generator inlet temperatures, through the use of ceramic materials, contribute the greatest amount to achieving fuel economy goals. Improved component efficiencies show significant additional gains in fuel economy.

Author

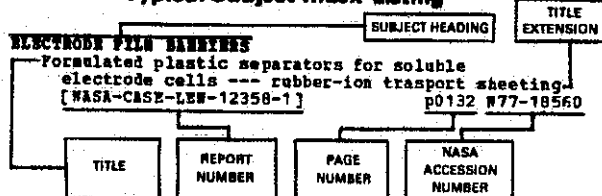
**99 GENERAL**

**A77-26505 \* #** Fundamental research needs - A status report of the task force on fundamental research. J. Anderson (NASA, Lewis Research Center, Bearings Branch, Cleveland, Ohio). *American Society of Mechanical Engineers, Winter Annual Meeting, New York, N.Y., Dec. 5-10, 1976, Paper 76-WA/RGPC-5*. 7 p. Members, \$1.50; nonmembers, \$3.00.

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- IONIC PROPELLANTS**  
U ION ENGINES
- IONIZATION**  
NT GAS IONIZATION
- NT ION PRODUCTION RATES**
- NT NONEQUILIBRIUM IONIZATION**

# IONIZED GASES

## IONIZED GASES

NT CESIUM PLASMA  
NT CHARGED PARTICLES  
NT COLD PLASMAS  
NT PLASMAS (PHYSICS)  
NT TOROIDAL PLASMAS

## IONIZED PLASMAS

U PLASMAS (PHYSICS)

## IONIZING RADIATION

NT GAMMA RAYS

NT ULTRAVIOLET RADIATION

\*Nonpropulsive applications of ion beams

[NASA-TM-X-73511]

p0166 N77-12847

## IONS

NT ANIONS  
NT HYDROGEN IONS  
NT METAL IONS

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U COMPUTERIZED SIMULATION

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NT STAINLESS STEELS  
NT STEELS

Weldability of high toughness Fe-12% Ni alloys  
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p0080 A77-28707

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## IRRITATION

NT TOXICITY AND SAFETY HAZARD

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U POTENTIAL FLOW

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U FERROMAGNETISM

U MATHEMATICAL MODELS

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**UNITED STATES OF AMERICA**

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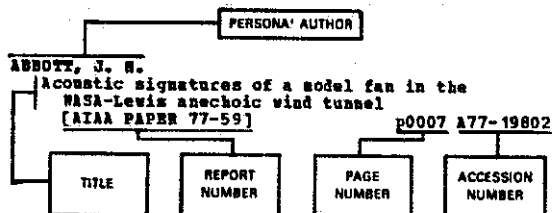
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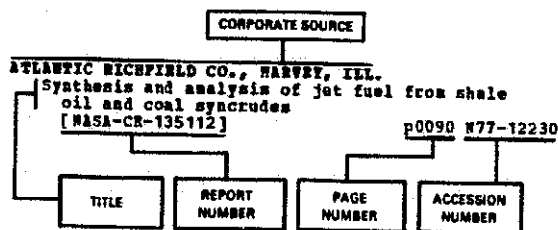
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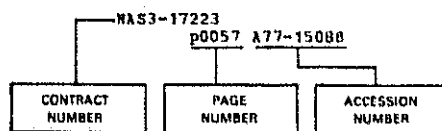
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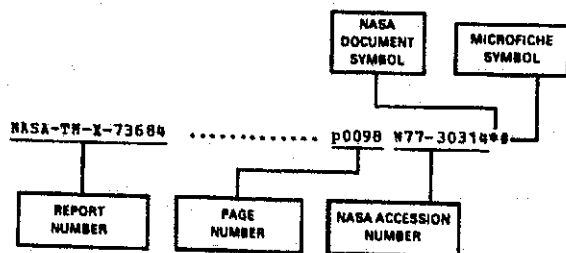
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